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BIOLOGICAL SCIENCES

BIOMORPHOLOGICAL FEATURES AND DISTRIBUTION ZONES OF THE GENUS *NARCISSUS* L. IN THE FLORA OF THE NAKHCHIVAN AUTONOMOUS REPUBLIC

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БИОМОРФОЛОГИЧЕСКИЕ ОСОБЕННОСТИ И ЗОНЫ РАСПРОСТРАНЕНИЯ РОДА *NARCISSUS* L. ВО ФЛОРЕ НАХЧИВАНСКОЙ АВТОНОМНОЙ РЕСПУБЛИКИ

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Abstract

The flora of the Nakhchivan Autonomous Republic includes 4 species of the genus *Narcissus* L. (*Narcissus lacticolor* (Haw.) Steud., *Narcissus poeticus* L., *Narcissus pseudonarcissus* L., *Narcissus tazetta* L.). These species are cultivated for rejuvenation purposes in new ornamental gardens. Subsequently, *Narcissus poeticus* L. and *Narcissus tazetta* L. were planted in the Nakhchivan State University Botanical Garden. The biomorphological characteristics and regions of the auxiliary species of the genus *Narcissus* L. in the flora of the Nakhchivan Autonomous Republic were studied. Renewed and artificial silk are widely used in the decoration of gardens and parks.

Аннотация

Четыре вида рода Narcissus L. (*Narcissus lacticolor* (Haw.) Steud., *Narcissus poeticus* L., *Narcissus pseudonarcissus* L., *Narcissus tazetta* L.), входящие во флору Нахчыванской Автономной Республики, широко распространены. Эти виды в основном культивируются в ландшафтном дизайне в декоративном садоводстве. Кроме того, виды *Narcissus poeticus* L. и *Narcissus tazetta* L. высажены в Ботаническом саду Нахчыванского государственного университета. Изучены биоморфологические характеристики и зоны распространения видов рода *Narcissus* L., входящих во флору Нахчыванской Автономной Республики. Установлено, что эти виды широко используются в декорировании садов и парков, главным образом в городских и районных центрах.

Keywords: *Narcissus* L., genus, species, distribution area, biomorphological characteristics.

Ключевые слова: Narcissus L., род, вид, ареал распространения, биоморфологические характеристики.

Introduction. The territory of the Nakhchivan Autonomous Republic, with its unique nature and rich flora, is considered one of the oldest regions in terms of its formation and formation. When examining the geological past of the territory, it becomes clear that tropical forests existed here. However, later, as a result of sharp climate change, as well as the displacement of continents and other geological processes, a modern soil-climate and corresponding flora biodiversity emerged here. Therefore, the modern territory of the Nakhchivan Autonomous Republic occupies an important place in the South Caucasus with its genesis and geographical position.

The study of the biomorphological characteristics of Narcissus L. species, which are widespread in the territory of the autonomous republic and are of great importance in enriching the flora, as well as in medicinal and decorative aspects, is a topical issue.

More than 60 species of the genus *Narcissus* are distributed in the humid high mountain meadows and grassy slopes of the territories from Central Europe to North Africa, from Western Europe to Western Asia. Four species of the genus are distributed in the flora of the Republic of Azerbaijan, including the Nakhchivan Autonomous Republic, of which three are cultivated and one species (*Narcissus* lacticolar) is distributed in the wild.

Material and methods. The material for the study was taken from species belonging to the genus Narcissus L., distributed in the territory of the Nakhchivan Autonomous Republic. In determining the species, works such as A.A. Grossheim "Flora of the Caucasus", "Flora of Azerbaijan" [A.A. Grossheim, 1957, 1945], L.I. Prilipko [Prilipko L.I., 1970], S.K. Cherepanov [Cherepanov S.K., 1995], and the Summary of the "Flora of the Caucasus", etc. were used. The latest taxonomic changes were clarified using World Flora Online [8].

In specifying the names of plants distributed in the area, the works of E.M. Gurbanov "Systematics of Higher Plants", A.M. Askerov "Plant World of Azerbaijan", T.H. Talibov, A.Sh. Ibrahimov and A.M. Ibrahimov were used [A.M. Askerov, 2016; E.M. Gurbanov, 2009; T.H. Talibov, A.Sh. Ibrahimov, A.M. Ibrahimov, 2021].

Discussion of the results. The genus *Narcissus* L., which is included in the flora of the Nakhchivan Autonomous Republic, is represented by 4 species

(*Narcissus lacticolor* (Haw.) Steud., *Narcissus poeticus* L., *Narcissus pseudonarcissus* L., *Narcissus tazetta* L.).

The bulbs of the species *Narcissus lacticolor* (Haw.) Steud. are 4 cm wide, spherical-ovate in shape, covered with dark brown scales. The leaves are 12 mm wide, linear in shape, equal to the corolla. The upper side of the leaf is connected to the umbel-shaped corolla at the base. The umbel consists of 5-7 flowers. The inflorescence is white, with ellipsoidal wide sections, tubular. The corolla is yellowish-golden in color, narrow, cup-shaped, with entire edges. The tube is relatively longer than the corolla.

Narcissus lacticolor (Haw.) Steud. is distributed wildly around the villages of Agbulag, Kuku, and Ashagi Qishlag in Shahbuz district, in the area of Mazra village in Ordubad district, and in the areas of Leketagh in Julfa district.

The plant is cultivated for decorative purposes in the cultural flora of Azerbaijan, mainly in the Agsu and Kurdamir districts and in the Nakhchivan Autonomous Republic, in the decoration of parks.

The stem of *Narcissus poeticus* L. is 20-40 cm high and bilateral. Its bulbs are 25-40 cm wide, spherical-ovate in shape, covered with dark brown scales. Its leaves are 5-9 mm wide, linear, lobed, smooth on the surface, light green in color, and approximately equal to the flower stalk. Its flowers are large and solitary. The inflorescence is tubular, whitish-green, obovate in shape, and pointed. The corolla is cup-shaped, orange-red in color, the edges of the petals are toothed, and the flowers are fragrant. The plant is an early spring plant, producing flowers and seeds in March-April.

Narcissus poeticus is widely used as an ornamental plant, in landscaping gardens and parks. Due to the amount of essential oil it contains, it is used in the perfume industry. The plant is mainly planted in parks and gardens in the Nakhchivan Autonomous Republic, mainly in Nakhchivan city, Sharur city, and Ordubad city.

The species *Narcissus poeticus* L. is cultivated in the Botanical Garden of Nakhchivan State University.

The stem of *Narcissus pseudonarcissus* L. is 40 cm high. Its bulbs are 2.5-4 cm wide, spherical-ovate in shape, covered with dark brown scales. The stem is flattened, single-flowered. Its leaves are 4-6 in number, linear, oblong, flat-topped, grayish green, located below or equal to the flower stalk. Its flowers are 5 cm long, located horizontally to the stem, the corolla is yellow. The perianth is broadly lanceolate, light yellow, with long tubular stamens. The pistil is broadly tubular, hairy on the surface, and the mouth is pubescent. The plant produces flowers and seeds in March - April.

Narcissus pseudonarcissus L. is cultivated as an ornamental plant in the cultural flora of the Nakhchivan Autonomous Republic. It is widely found in parks mainly in the Nakhchivan city area and in the Ordubad, Julfa, and Shahbuz districts.

Narcissus tazetta L. The stem is 30-50 cm high, flattened. The leaves are linear, grayish green, oblong, and equal to the peduncle. The bulbs are 3-5 cm wide, spherical to ovoid in shape. The corolla is included in the umbel flower group consisting of 3-15 flowers, cup-shaped, the flowers are entire, yellow in color. The perianth is white, obovate in shape.

The plant is native to the Mediterranean region. It is mainly cultivated as an ornamental plant in the cultural flora.

Narcissus tazetta L. species is cultivated for decorative purposes in gardens and parks in the areas of Qivrag village of Kangarli district, Heydarabad settlement of Sadarak district, Sharur district, and Shahbuz district in the Nakhchivan Autonomous Republic. It is also used to decorate flower bouquets.

Result. During the study, it was found that the genus *Narcissus* L. is represented by 4 species (*Narcissus lacticolor* (Haw.) Steud., *Narcissus poeticus* L., *Narcissus pseudonarcissus* L., *Narcissus tazetta* L.) in the cultivated and wild flora of the Nakhchivan Autonomous Republic. The species *Narcissus lacticolor* (Haw.) Steud. is found in the wild flora of the autonomous republic around the villages of Agbulag, Kuku, and Ashagi Qishlag of the Shahbuz region, in the area of the village of Mazra of the Ordubad region, and in the areas of Leketagh of the Julfa region. The species *Narcissus poeticus* L., *Narcissus pseudonarcissus* L., and *Narcissus tazetta* L. are cultivated for decorative purposes in the landscaping of gardens and parks. During the study, the bioecological characteristics and distribution zones of the species were studied.

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CHEMICAL SCIENCES

SYNTHESİS AND FTIR CHARACTERİZATİON OF NEW NİTROGEN-RİCH CONDENSATİON PRODUCTS DERİVED FROM ALLANTOİN AND DİCYANDİAMİDE

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Abstract

New nitrogen-rich condensation products were obtained from the reaction of allantoin ($C_4H_6N_4O_3$) with dicyandiamide ($C_2H_4N_4$) under acidic and neutral conditions. Reflux in concentrated hydrochloric acid afforded the solid product LG-5, which could be separated into an ethanol-insoluble fraction (LG-5A) and an ethanol-soluble fraction (LG-5B). When distilled water was used instead of HCl, a different condensation product, LG-6, was isolated. The compounds were characterized by FTIR spectroscopy and compared with the parent substrates.

LG-5A and LG-5B show broad bands in the 3435–3190 cm^{-1} region attributable to overlapping N–H and O–H stretching vibrations, together with a characteristic carbonyl pattern consisting of a strong band at ca. 1778 cm^{-1} and additional bands at ≈1700–1650 cm^{-1} assigned to C=O/C=N modes of a ureide-type framework. In both fractions the sharp ν(C≡N) bands of dicyandiamide disappear, indicating complete consumption of the nitrile groups during condensation. LG-6, obtained in water, preserves intense bands at 2199 and 2158 cm^{-1} due to nitrile stretching, but still exhibits shifted carbonyl bands compared with allantoin, evidencing partial condensation.

Comparison of the spectra demonstrates that the reaction pathway and the degree of conversion of nitrile functions are strongly dependent on the reaction medium. The FTIR data support the formation of new nitrogen-rich heteroconjugated systems and show small but systematic spectral differences between LG-5A and LG-5B, consistent with distinct solid-state forms or closely related isomers.

Keywords: allantoin; dicyandiamide; nitrogen-rich compound; condensation reaction; FTIR; nitrile consumption; hydrochloric acid vs water.

Introduction

Nitrogen-rich organic compounds attract increasing interest because of their potential applications as corrosion inhibitors, energetic materials, catalysts and multifunctional ligands. Condensation reactions between ureides and cyano-containing amidines offer a convenient route to such structures, often producing densely functionalized frameworks that combine carbonyl, amide, imide and imino functions in a single molecule.

Allantoin is a bicyclic ureide that contains two carbonyl groups and multiple N–H donors and can therefore act as both nucleophile and electrophile under suitable conditions. Dicyandiamide (cyanoguanidine) is a highly functionalized bis-guanidine carrying two nitrile groups and four exocyclic nitrogen atoms. Its condensations with various carbonyl compounds frequently lead to amidines, guanidinium salts and polymeric networks.

In our previous work on the allantoin–dicyandiamide system we observed the formation of nitrogen-rich products under acidic reflux conditions. However, the influence of the reaction medium and the detailed spectroscopic features of the individual fractions remained unclear.

The aim of the present study is (i) to prepare new products arising from the interaction of allantoin and dicyandiamide in hydrochloric acid and in water, (ii) to separate the solid obtained in acid into two fractions (LG-5A and LG-5B) and (iii) to compare their FTIR spectra with each other and with that of the product formed in water (LG-6) and with the starting materials. The discussion focuses on the changes in functional-group regions, especially in the ν(OH/NH), ν(C=O), ν(C=N) and ν(C≡N) ranges, in order to draw conclusions about the course of the condensation.

Experimental

Materials

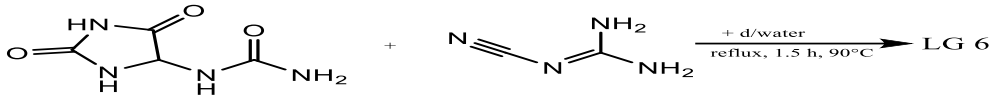
Allantoin (R_1, $C_4H_6N_4O_3$, 158.12 $g \cdot mol^{-1}$) and dicyandiamide (R_2, $C_2H_4N_4$, 84.08 $g \cdot mol^{-1}$) were of analytical grade and used without further purification. Concentrated hydrochloric acid (R_3, 37% reagent grade) and distilled water were employed as received. Ethanol (96%) was used for work-up and fractionation.

Thin-layer chromatography (TLC) was monitored under UV light using a **CAMAG UV Cabinet 4**.

Synthesis of LG-5 (LG-5A and LG-5B)

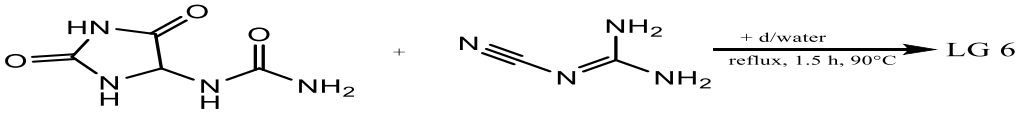
Allantoin and dicyandiamide were mixed in an appropriate molar ratio (typically close to 1:1) in concentrated hydrochloric acid (6 mL). The suspension was heated under reflux with stirring until a homogeneous mixture was obtained and the TLC of the starting materials indicated substantial conversion. After cooling to room temperature, the solid product (LG-5) was filtered, washed with cold water to remove inorganic salts and dried in air.

LG-5 was suspended in hot ethanol. The ethanol-insoluble fraction was collected by filtration and designated **LG-5A**. The ethanol-soluble portion was concentrated to give the second fraction, **LG-5B**. Both solids were dried to constant mass before FTIR analysis.



Synthesis of LG-6

For LG-6, the same starting materials were combined in distilled water instead of HCl. The mixture was heated under reflux with stirring. After completion (monitored by TLC), the reaction mixture was cooled, and the resulting solid was filtered, washed thoroughly with water and ethanol and dried to give **LG-6**.



FTIR measurements

FTIR spectra were recorded in the range 4000–400 cm^{-1} as KBr pellets (or ATR mode, according to your actual procedure) using an Agilent Cary 630 FTIR spectrometer. Spectra were collected for the starting materials (allantoin and dicyandiamide) and for the isolated products LG-5A, LG-5B and LG-6.

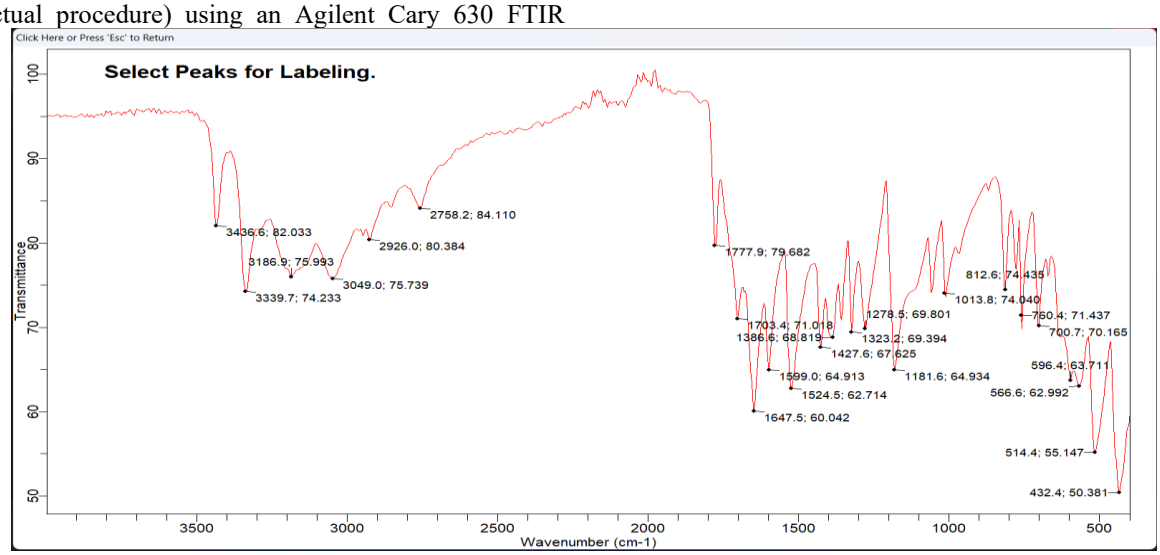


Figure 1- FTIR Analysis Overlay of LG 5AUsing Agilent Technologies Cary 630 FTIR Device

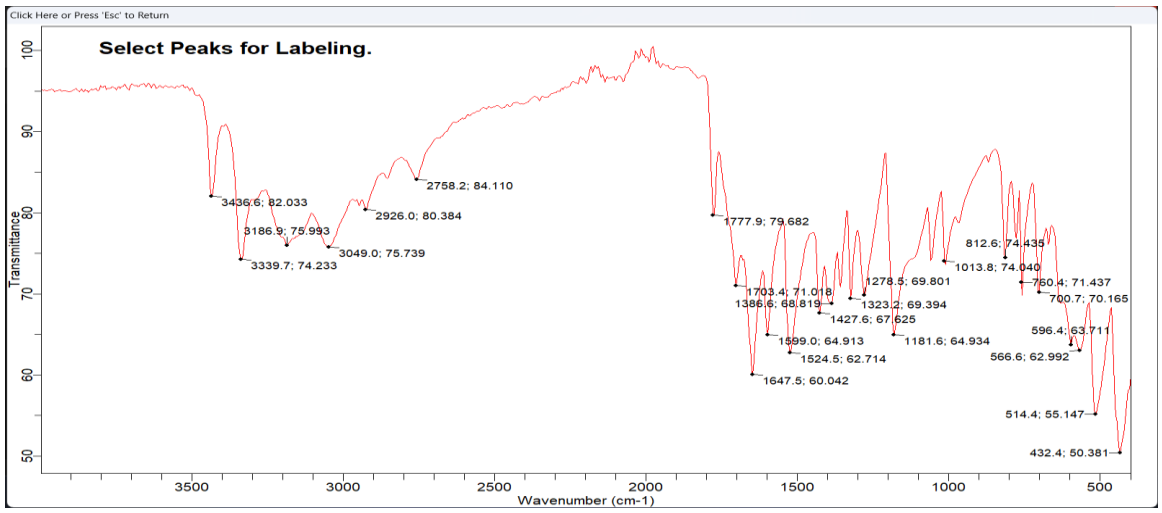


Figure 2- FTIR Analysis Overlay of LG 5BUsing Agilent Technologies Cary 630 FTIR Device

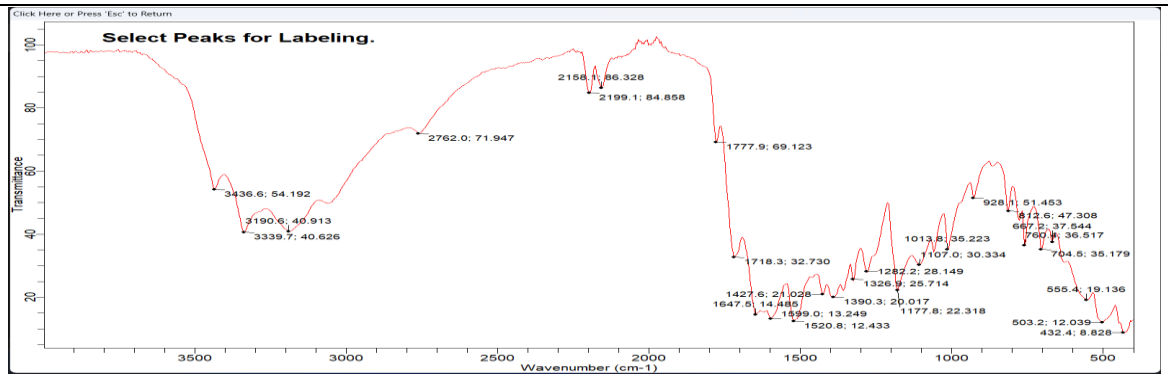


Figure 3- FTIR Analysis Overlay of LG 6 Using Agilent Technologies Cary 630 FTIR Device

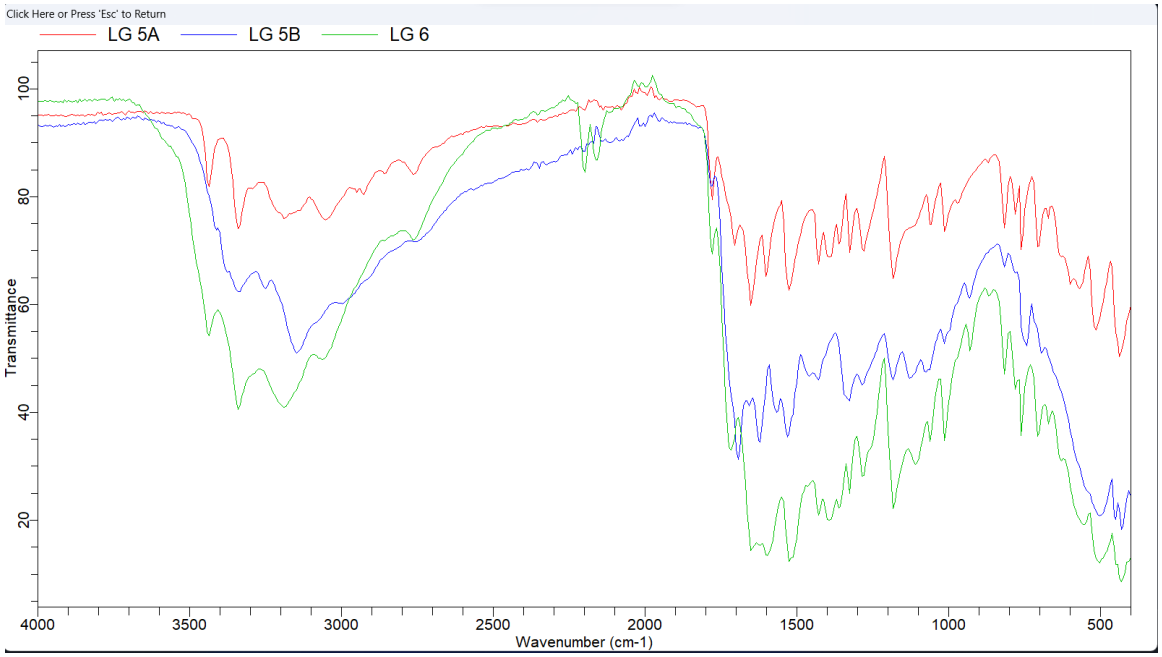


Figure 4- FTIR Analysis Overlay of LG5A-LG5B-LG6 .Using Agilent Technologies Cary 630 FTIR Device

3. Results and Discussion

3.1. FTIR features of the starting materials

Allantoin exhibits a broad band in the 3500–3200 cm^{-1} region due to overlapping ν(N–H) and ν(O–H) vibrations of the ureide and imide functions. Two strong carbonyl stretching bands are typically observed at about 1770 and 1720 cm^{-1}, characteristic of the imidazolidinedione ring. Additional bands in the 1450–1300 cm^{-1} interval correspond to C–N and C–O stretching modes, while the region below 1000 cm^{-1} contains ring-deformation vibrations.

Dicyandiamide shows N–H stretching bands around 3400–3200 cm^{-1} and, very characteristically, intense sharp bands in the 2200–2100 cm^{-1} region attributed to the ν(C≡N) stretching of the two nitrile groups. Bands near 1650–1600 cm^{-1} can be assigned to C=N and C–N stretching within the cyanoguanidine framework.

3.2. FTIR spectrum of LG-5A

The single-compound spectrum of LG-5A (Fig. 1) shows a very broad absorption between about 3500 and 3100 cm^{-1} with resolved maxima at **3436**, **3339** and **3187 cm^{-1}**. This broad envelope reflects multiple hydrogen-bonded N–H and O–H groups, indicating that LG-5A retains the strongly hydrogen-bonded ureide character of allantoin but in a modified environment.

In the C–H stretching region, weaker bands at **3049**, **2926** and **2758 cm^{-1}** are observed. The band near 3049 cm^{-1} is attributable to aromatic/heterocyclic C–H stretching, whereas the 2926–2758 cm^{-1} features correspond to aliphatic C–H and possibly to overtones associated with protonated nitrogen centres ($–NH_3^+$) formed in the acidic medium.

The carbonyl/imino region of LG-5A differs significantly from that of the individual starting reagents. A strong band appears at **1777 cm^{-1}**, close to the higher-frequency C=O of allantoin but slightly shifted, indicating that at least one carbonyl group remains in a similar but not identical environment. Additional strong bands and shoulders are observed around **1703**, **1680** and **1648 cm^{-1}**. These can be assigned to overlapping ν(C=O) and ν(C=N) vibrations of a more extended conjugated system formed by condensation of allantoin with dicyandiamide. The presence of a distinct band near 1648 cm^{-1} is typical for C=N or amide-II-type vibrations in guanidinium and amidine structures.

Importantly, **no strong absorptions are observed in the 2200–2100 cm^{-1} region**. The absence of the nitrile bands that are prominent in dicyandiamide

demonstrates that both cyano groups have been consumed during the reaction, most likely through nucleophilic addition of allantoin followed by tautomerization and protonation.

In the fingerprint region, LG-5A displays intense bands at approximately **1590**, **1524**, **1428**, **1365** and **1323 cm⁻¹**, together with a series of peaks between **1278** and **1000 cm⁻¹**. These bands can be ascribed to δ(N–H), ν(C–N), ν(C–O) and ring-deformation modes of the newly formed nitrogen-rich framework. The strong bands centred at **1182**, **1014** and around **812–700 cm⁻¹** suggest a complex pattern of C–N and C–O stretches coupled with out-of-plane N–H deformations.

Overall, the LG-5A spectrum confirms the formation of a condensed ureide–guanidine system in which the nitrile groups of dicyandiamide are fully transformed and the carbonyl environment of allantoin is significantly altered.

3.3. FTIR spectrum of LG-5B and comparison with LG-5A

LG-5B originates from the ethanol-soluble fraction of the crude LG-5 product. Its overlaid spectrum with the starting reagents (Fig. 4) shows the same main features as LG-5A:

- a broad ν(OH/NH) band between 3500 and 3100 cm⁻¹,
- absence of the intense ν(C≡N) bands of dicyandiamide,
- a strong carbonyl/imino band near 1775–1780 cm⁻¹ and additional C=O/C=N bands in the 1700–1650 cm⁻¹ range, and
- a similar pattern of C–N/C–O bands in the fingerprint region.

However, closer inspection of Fig. 4 reveals subtle but reproducible differences between LG-5A and LG-5B:

- The broad ν(OH/NH) envelope of LG-5B is slightly shifted to lower wavenumbers and appears even broader, which can be attributed to stronger or more diverse hydrogen bonding in this fraction.
- The relative intensity ratio of the high-frequency carbonyl band (≈1778 cm⁻¹) to the lower-frequency bands (≈1700–1650 cm⁻¹) is somewhat different, suggesting a small variation in the number or type of carbonyl groups in equivalent environments.
- In the fingerprint region, some bands (for example near 1390–1360 and 1280–1240 cm⁻¹) are either intensified or slightly shifted.

These differences, although small, indicate that LG-5A and LG-5B are not identical but most likely correspond to closely related structures – for instance, different protonation states, tautomers or solid-state polymorphs of the same basic condensation product. The higher solubility of LG-5B in ethanol is consistent with a structure containing more protonated or less extensively hydrogen-bonded sites.

3.4. FTIR spectrum of LG-6 and comparison with LG-5

The FTIR spectrum of LG-6 (Fig. 5) again shows a broad ν(OH/NH) band in the 3500–3200 cm⁻¹ region, with maxima at **3436**, **3339** and **3190 cm⁻¹**, similar to LG-5A/B and confirming the presence of multiple N–H/O–H functionalities.

A key difference appears in the triple-bond region: **LG-6 exhibits two intense bands at 2199 and 2158 cm⁻¹**. These are characteristic of ν(C≡N) stretching and essentially coincide with the nitrile bands of dicyandiamide. Their presence demonstrates that, in water, at least one cyano group of the initial reagent remains unreacted or is regenerated in the final product. Thus the condensation in neutral medium is less complete than in hydrochloric acid.

The carbonyl region of LG-6 also shows significant changes relative to the starting materials. A strong band at **1777 cm⁻¹** and additional bands at **1718** and **1647 cm⁻¹** indicate that, as in LG-5, the carbonyl groups of allantoin participate in condensation but are not fully transformed. The band at 1647 cm⁻¹ is again assigned to C=N / amide-II modes, confirming that some guanidine-type linkage is formed even in the aqueous reaction.

In the fingerprint region, LG-6 displays bands at **1590**, **1520**, **1390**, **1325** and **1282 cm⁻¹**, and a series between **1178** and **1000 cm⁻¹** similar to those of LG-5. Nevertheless, the relative intensities differ, and additional shoulders appear around **928** and **812 cm⁻¹**, which may reflect different ring-deformation and N–H out-of-plane modes due to the presence of residual nitrile groups and a less condensed framework.

The comparison of Fig. 2, 4 and 6 clearly illustrates these trends:

- all LG products show a broadened ν(OH/NH) region relative to the starting materials, consistent with an increase in hydrogen-bonding possibilities;
- LG-5A and LG-5B lack ν(C≡N) bands, indicating complete consumption of nitriles;
- LG-6 retains strong nitrile bands, implying partial condensation;
- all products show shifted carbonyl patterns compared to allantoin, evidencing modification of the ureide core.

3.5. Proposed structural changes

Although full structural elucidation requires additional methods (NMR, elemental analysis, mass spectrometry and possibly X-ray diffraction), the FTIR data allow some qualitative conclusions:

1. **Condensation through nitrile groups.** The disappearance of ν(C≡N) in LG-5A and LG-5B suggests that both cyano groups of dicyandiamide react, likely via nucleophilic addition of the allantoin N–H followed by protonation and tautomerization to amidine/guanidinium functionalities.
2. **Modification of the allantoin carbonyls.** Shifts of the carbonyl bands from 1770/1720 cm⁻¹ (allantoin) to 1777/1700–1650 cm⁻¹ in the products indicate that one or both carbonyl groups are involved in conjugation with newly formed C=N bonds, giving rise to a more delocalized system.
3. **Effect of reaction medium.** The acidic medium (concentrated HCl) promotes deeper condensation, pushing the reaction to complete nitrile consumption and forming the more compact nitrogen-rich frameworks LG-5A and LG-5B. In contrast, the neutral aqueous medium leads to LG-6, where the nitrile functions are only partly engaged, leaving significant ν(C≡N) intensity.

4. **Solid-state diversity.** The small but consistent spectral differences between LG-5A and LG-5B, together with their distinct solubility, point to either polymorphism or closely related isomeric forms (for example different protonation patterns or hydrogen-bonding networks) of the same basic condensation scaffold.

These observations highlight how a simple change of solvent (HCl vs water) can drastically alter the degree of condensation and the functional-group composition of the final nitrogen-rich products.

4. Conclusions

Allantoin and dicyandiamide react to form new nitrogen-rich condensation products whose structure strongly depends on the reaction medium. Under concentrated hydrochloric acid, the nitrile groups of dicyandiamide are completely consumed, and the solid product LG-5 can be separated into two closely related fractions, LG-5A and LG-5B, differing mainly in hydrogen-bonding environment and solubility. In water, a different product LG-6 is obtained, which still contains intact nitrile groups, as evidenced by intense FTIR bands at 2199 and 2158 cm^{-1}.

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ECONOMIC SCIENCES

THE DEVELOPMENT DYNAMİCS AND KEY FACTORS SHAPİNG GREEN TOURİSM İN AZERBAİJAN

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Abstract

Green tourism, encompassing ecotourism and sustainable tourism practices, has become a strategic focus for countries seeking to balance economic development with environmental conservation. In Azerbaijan, the tourism sector has experienced dynamic growth over the past decade, driven by state policy, infrastructure investments, market diversification, and institutional development. This study analyzes the dynamics of green tourism in Azerbaijan and identifies the main factors influencing its formation and growth. Using a mixed-methods approach, the research combines quantitative analysis of tourism statistics (2015–2023) with qualitative assessment of policy initiatives, infrastructure development, and institutional programs. The findings indicate that the growth of green tourism has been shaped by six interrelated factors: strategic state support, tourism infrastructure expansion, visa liberalization and international promotion, evolving domestic and global market demand, integration of new territories into the tourism sector, and human resource and institutional development. The study also highlights the impact of the COVID-19 pandemic on domestic and foreign tourism flows and the subsequent recovery phase. By providing a comprehensive overview of green tourism dynamics and the underlying determinants, this research offers practical insights for policymakers, tourism planners, and stakeholders seeking to enhance sustainable tourism development in Azerbaijan.

Keywords: Green tourism, ecotourism, sustainable tourism, Azerbaijan, tourism policy, infrastructure development, tourism dynamics, COVID-19, tourism statistics, environmental tourism

Introduction

Tourism is widely recognized as one of the most significant sectors in the global economy, contributing not only to economic growth but also to social development, cultural exchange, and environmental awareness. In recent years, the focus on **sustainable and environmentally responsible tourism**, commonly referred to as *green tourism*, has intensified worldwide. Green tourism emphasizes the conservation of natural resources, protection of biodiversity, and promotion of ecologically sensitive travel, while simultaneously providing economic and social benefits to local communities. This trend reflects a growing global awareness of environmental challenges and the need for sustainable development in the tourism sector.

The Republic of Azerbaijan has demonstrated considerable progress in tourism development since gaining independence. Leveraging its rich cultural heritage, diverse landscapes, and unique ecological resources, Azerbaijan has pursued a strategy aimed at **diversifying its tourism sector**, promoting both traditional and nature-based tourism. The adoption of the *Tourism Development Strategy (2016)* and the *"Azerbaijan 2023" Strategic Roadmap* marked a decisive shift in state policy, positioning tourism as a priority sector of the national economy. Complementary initiatives, such as visa liberalization, infrastructure investment, and the establishment of a dedicated State Tourism Agency, have further enhanced the country's appeal to international and domestic tourists alike.

In this context, the development of **green tourism in Azerbaijan** has emerged as a key area of both research and practical policy implementation. Ecotourism and nature-based recreation have gained popularity among foreign and domestic visitors, particularly in regions with national parks, mountainous landscapes, and culturally significant rural areas. The COVID-19 pandemic temporarily disrupted tourism flows, but it also underscored the potential of domestic ecotourism as people sought nature-based and socially distanced travel experiences. The subsequent recovery period highlights both the resilience of the tourism sector and the strategic importance of sustainable tourism development.

Methodology

This study employs a **mixed-methods research design**, combining **quantitative statistical analysis** with **qualitative analytical methods** to examine the dynamics of green tourism and the main factors influencing its formation in the Republic of Azerbaijan. The use of a mixed approach allows for a more comprehensive assessment of tourism trends, policy impacts, and structural changes in the sector over time.

The research is **analytical** in nature. It aims not only to describe changes in tourism indicators but also to identify causal relationships between state policy, infrastructure development, demand patterns, and the evolution of green tourism.

Data Sources

The study relies primarily on secondary data obtained from official and reliable sources, including:

- Statistical bulletins of the State Statistics Committee of the Republic of Azerbaijan
- Data from the State Tourism Agency of Azerbaijan
- Information provided by the State Border Service

- Reports and strategic documents such as the *Tourism Development Strategy* and the *"Azerbaijan 2023" Strategic Roadmap*
- Publications of international organizations and academic literature on ecotourism and sustainable tourism

Tourism data covering the period 2015–2023 were used to analyze long-term trends, pre-pandemic growth, pandemic-related decline, and post-pandemic recovery.

Literature Review

Green tourism, also known as ecotourism or sustainable tourism, emphasizes environmental conservation, cultural preservation, and socio-economic benefits for local communities. According to Bramwell and Lane (1993), sustainable tourism is an evolving global approach that seeks to balance economic growth with environmental and social sustainability. Buckley (2012, 2016) highlights that ecotourism is a subset of sustainable tourism, characterized by responsible travel to natural areas that conserves the environment and improves the well-being of local populations. Fennell (2017) further argues that ecotourism encompasses educational experiences, environmental awareness, and direct participation in conservation activities, making it a tool for both environmental and social development. Honey (2017) emphasizes that successful ecotourism requires a combination of regulation, community involvement, and market-based incentives to ensure sustainability.

The global tourism industry has witnessed a shift from mass tourism toward alternative and environmentally sensitive travel. D. R. Toubes and Araújo-Vila (2022) note that the green economy and ecotourism are increasingly intertwined, reflecting a rising demand for environmentally conscious tourism products. Similarly, Fudurich and MacKay (2020) highlight the role of environmentally certified accommodations, such as eco-friendly Airbnb options, in influencing tourist behavior. Samal (2023) demonstrates that tourists' environmental awareness strongly shapes their travel choices, emphasizing the need for sustainable tourism infrastructure and practices. Scheyvens (1999) stresses that ecotourism can empower local communities by providing income opportunities while promoting environmental stewardship. Humeniuk (2021) underscores the importance of rural green tourism in sustainable regional development, noting that natural landscapes, cultural heritage, and community participation are critical for its success.

In the context of Azerbaijan, green tourism has emerged as a significant component of the national tourism strategy. The tourism sector in Azerbaijan has experienced rapid growth since independence, supported by legislative reforms, strategic programs, and infrastructure development (Beidyk, 2018; SM & SS, 2025). According to Huseynova and Kazimov (2025), state investment and policy measures, including the simplification of visa regimes and international promotional campaigns, have contributed to increasing tourist inflows. Domestic researchers, such as Soltanova (2018), note the growing popularity of leisure and recreational tourism, reflecting a rising interest in ecotourism and nature-based travel. Infrastructure improvements, including the expansion of hotels and transport networks, have also facilitated the development of green tourism in regions such as Guba, Gabala, Sheki, and Gusar.

Huseynova and Qurbanova (2025) and Alirzayev and Huseynova (2025) emphasize that macroeconomic stability, investment incentives, and strategic economic reforms have indirect but significant effects on the tourism sector, including green tourism. The work of Paniuk (2020) and Humeniuk (2021) supports the notion that ecological tourism contributes not only to environmental sustainability but also to the socio-economic development of rural areas, which is particularly relevant for Azerbaijan's regional tourism planning.

Effective institutional frameworks and policy interventions are crucial for the development of green tourism. In Azerbaijan, the creation of the State Tourism Agency, strategic roadmaps, and ecotourism associations (Huseynova & Balajayeva, 2025) has strengthened coordination between government bodies, private enterprises, and non-governmental organizations. These institutions play a central role in creating eco-trails, eco-corridors, and community-based tourism initiatives. Buckley (2012) and Honey (2017) argue that institutional support is a key determinant of sustainable tourism, as it ensures adherence to environmental standards, fosters local engagement, and enhances international competitiveness.

The COVID-19 pandemic caused a significant decline in international tourism, highlighting vulnerabilities in the sector. According to UNWTO (2022) and www.stat.gov.az, Azerbaijan experienced a substantial reduction in tourist arrivals in 2020. However, domestic ecotourism gained prominence as residents sought nature-based recreation, a trend consistent with global patterns (Choban & Karakuş, 2019). The post-pandemic recovery (2022–2023) has seen renewed growth in tourist arrivals, supported by infrastructure improvements, market diversification, and government promotion, suggesting resilience and the strategic importance of green tourism in Azerbaijan's economic planning.

Comparative analyses and discussion:

The path taken by the tourism sector in Azerbaijan in recent years is quite interesting. In particular, the dynamic development of ecotourism and sustainable tourism, which we call "green tourism", is observed. Since the years of independence, the country has improved tourism legislation, and in 2016, the Tourism Development Strategy and later the "Azerbaijan 2023" Strategic Roadmap were adopted. Such steps have increased the state's attention to the tourism sector. For example, in 2017, an electronic visa system was introduced, and in 2018, a separate State Tourism Agency was established. So what was the result of these steps? First of all, a significant increase in the number of foreign tourists visiting Azerbaijan began to be recorded. While in 2015, approximately 2 million foreign tourists visited

the country , in 2019 this indicator exceeded 3 million for the first time, reaching a record . After this, a sharp decrease occurred in 2020 due to the pandemic, but a recovery trend was observed in the subsequent period. Table 1.1 shows the dynamics of foreign tourists visiting the country in recent years (2015–2023):

Table 1.1.

Number of foreign tourists visiting Azerbaijan (2015–2023)

Year	Number of foreign tourists (in people)
2015	2 006 176
2019	3 170 000
2020	1 299 400
2021	792,000
2022	1 602 000
2023	2 085 000

Source for Table 1.1. State Border Service data and statistical bulletins of the State Tourism Agency

As can be seen from the table, tourism in Azerbaijan grew rapidly in 2015–2019. In 2017, a record was set with 2.69 million foreign visitors. The growth continued in 2018 (2.85 million people), and in 2019, there was a historical maximum of about 3.17 million tourists. These indicators put Azerbaijan among the top 20 countries in the world with the fastest growing tourism sector (according to WHO reports), and tourism provided about 4.5% of GDP . There were several key factors in the formation of this successful dynamic.

The first factor is the state's tourism policy. The "State Program for Tourism Development 2008–2016" adopted in the 2010s, followed by the Strategic Roadmap approved in 2016, resulted in tourism being declared a priority sector. These documents envisaged measures such as the creation of tourism clusters in the regions, improving infrastructure, and increasing the quality of service. Gadir Bayramli (2024) notes that the successive reforms carried out during the period of independence, planned tourism policy, and public-private sector partnership have created a basis for the sustainable development of tourism in Azerbaijan . Indeed, the improvement of tourism legislation, the simplification of the visa regime (e-visa for 93 countries), and international promotional campaigns such as "Take Another Look" strengthened the flow of tourists in 2016–2019. For example, as a result of the simplification of visas in 2016 and the holding of the "Formula 1" races in Baku that year, the number of foreign tourists increased compared to 2015, reaching 2.24 million people. After the launch of the "ASAN Visa" system in 2017, the growth continued. During this period, a sharp increase in tourists, especially from Middle Eastern countries - Saudi Arabia, the UAE, was observed (from only a few hundred people in 2015 to tens of thousands in 2017). The largest share in the structure of foreign guests traditionally belonged to Russia, Georgia, Turkey and Iran, but in 2017–2019, distant markets such as India, China, and the Gulf Arab countries also began to come to the fore . This trend is consistent with the thesis in the scientific literature of the diversification of tourist interests against the backdrop of globalization and increasing air connections. For example, Düşmezkalender and Metin (2019) note in their research the trend of transition from mass tourism to alternative tourism in recent years and the increasing demand for nature-oriented, environmentally sensitive travel in diva-portal.org. The growth in the Azerbaijani tourism sector was also in line with this global trend.

2019 can be considered a peak in terms of green tourism dynamics. In that year, a record number of foreign tourists visited our country, but the main purpose was leisure and recreation. Table 2.1. shows the distribution of travel purposes of foreign visitors to Azerbaijan in 2019. As can be seen, more than half of tourists came to our country for leisure and entertainment (recreation), while the rest of the main shares were business trips and visits to relatives. Interestingly, the share of those who came for nature and recreation purposes increased compared to 2015. This is an indicator of the growing interest in green tourism.

Table 2.1..

Distribution of foreign visitors to Azerbaijan by tourism purposes (2019)

Tourism purpose	**Number of arrivals in 2019 (persons)**	**Share in total tourist flow (%)**
Leisure and recreation tourism	839 300	33.9%
Business tourism	834 400	33.7%
Medical and rehabilitation tourism	49 100	2.0%
Religious tourism	14 700	0.6%
Visiting relatives and friends	674 900	27.3%
Other tourism purposes	41 600	1.7%
Total tourism purposes	**2 454 000**	**100%**(those who come as tourists)
Other non-tourist trips (e.g. transit)	242,700	–

Source: From the State Statistics Committee, tourism statistical bulletin for 2019 .

From Table 2.1. we see that the majority of the 2.454 million people who visited the country as tourists were either for leisure (approximately 34%) or business (approximately 34%). That is, in 2019, one in three foreign visitors came to explore the natural and cultural resources of Azerbaijan and relax. This proportion has increased slightly compared to 2015. For example, in 2015, the number of people who came for leisure was 669 thousand, which constituted approximately 33% of the total number of tourists . As can be seen, over the past few years, the share of leisure (including ecotourism) has increased, equaling business trips. Local researchers such as Soltanova (2018) also note that in recent years, recreational trips have come to the fore among tourists in Azerbaijan. This result confirms the thesis of these authors. A little later (in Chapter 2.2), it is precisely the increase in ecotourism potential that will be linked to these statistics.

In 2020, the COVID-19 pandemic virtually paralyzed the tourism sector. Since March 2020, the borders have been closed, cutting off the flow of foreign tourists. As a result, only a few thousand foreigners were able to visit the country between April and December 2020. According to the State Statistics Committee, only 41 tourists visited national parks in 2020 – which clearly shows the impact of the pandemic. The total number of foreign tourists in 2020 remained at 1.3 million, most of whom arrived in the first two months of the year. The share of the tourism sector in GDP fell from 4.5% in 2019 to 1.9% in 2020 . In other words, the weight of tourism in the country's economy has suddenly tripled. This decline, of course, was also the focus of researchers. Huseyn (2021), analyzing the impact of the pandemic on Azerbaijani tourism, notes that in 2020, the added value created as a result of tourism activities decreased by 58.9% compared to the previous year . Our statistical analysis also shows the same result and confirms the conclusion of the same author. However, the pandemic also had a different impact on domestic tourism . The local population, unable to travel abroad, began to prefer trips within the country. In particular, recreation in the bosom of nature - that is, ecotourism - became more attractive for domestic tourists during the pandemic. This is a trend observed in many countries: people are moving from big cities to nature. Choban and Karakuş (2019) write that although the concept of nature-based tourism is new, in fact, people have long had an interest in national parks and sensitive ecosystems, but extreme conditions such as the pandemic have only intensified this interest diva-portal.org. In Azerbaijan, interest in domestic ecotourism routes also increased significantly in 2020-2021. For example, in 2021, during the 5 months when domestic travel was almost restored, 38.8 thousand domestic visitors visited national parks (while almost no one visited during the same period in 2020). Arzu Samadova, an official of the Ministry of National Environment, also noted that the flow of tourists to national parks is rapidly recovering after the pandemic, and in the first 5 months of 2021 alone, about 40 thousand tourists visited national parks.

2022-2023 is a period of recovery and new development of Azerbaijani tourism. With the opening of the borders, the arrival of foreign tourists gradually resumed. In 2022, the number of foreign tourists reached 1.6 million people - that is, although still significantly less than the pre-pandemic level, it was almost a two-fold increase compared to 2021. The increase continued in 2023, and by the end of the year the number of foreign visitors to the country increased to 2.09 million people . That is, for the first time since the pandemic, the 2 million mark was exceeded. However, the structure of the tourism market has undergone some changes. Vugar Bayramov (2024) states that in the structure of the countries of origin of tourists arriving in 2023, the share of European and Asian countries increased, while the number of visitors from the Gulf countries decreased slightly . For example, while the number of tourists from the European Union countries increased by 41.6% during the first 10 months of 2023, the number of tourists from Arab countries decreased by 7.4% . This shows that Azerbaijan is succeeding in attracting tourists from new markets in the post-pandemic period. In particular, there has been a more than 2-3-fold increase in the number of tourists from the countries of the Asia-Pacific region - China, South Korea, as well as the Central Asian republics (Turkmenistan and Kazakhstan). This is the result of the state's efforts to strengthen tourism relations with these countries in recent years (for example, opening direct flights, promoting mutual tourism).

Another factor in the formation of green tourism is the development of infrastructure. Tourism infrastructure includes both transport (roads, flights) and accommodation facilities (hotels, country houses). In 2015-2023, both the number and quality of hotels in Azerbaijan increased significantly. New hotels and routes were opened not only in Baku and Absheron, but also in the regions. Table 2.3 shows the growth of hotel infrastructure in recent years. While in 2017 there were only ~550 hotels in the country, by 2024 this figure had reached approximately 800 (+44% increase in 8 years). The one-time capacity of hotels increased by 62% between 2017 and 2024, from ~47 thousand to 76 thousand people . In 2018 alone, 33 new hotels were commissioned in the country . Among these facilities, mountain and spa hotels in regions such as Guba, Gabala, Sheki, and Gusar should be especially noted.

Table 2.3.

Number and capacity of hotels in Azerbaijan (by selected years)

Indicator	2018	2021	2024 (approx.)
Number of hotels (units)	596	685	~800
Simultaneous accommodation capacity in hotels (persons)	46 700	60,000 (approx.)	~76,000
Number of hotel rooms (units)	22 200	27,000 (approx.)	~36,000 (calc.)

Source: State Statistical Committee and State Tourism Agency (annual statistical bulletins) (Note: Figures for 2024 are estimated based on 2017-2024 growth rates.)

As can be seen from Table 2.3, the accommodation infrastructure has grown qualitatively. The increase in the number of hotels means that the country is ready to receive more tourists. At the same time, the opening of many new hotels and guest houses in the regions has created a base, especially for green tourism. For example, in the Shahdag-Gusar region, while in 2015 there were only a few hotels, in 2023 there were already dozens of hotels and ski-tourism complexes of various categories (3-4-5 stars). In 2019, the road to the Shahdag Tourism Center and other infrastructure were improved, and new rural tourism routes were formed. Without these investments, it would be difficult to observe the influx of tens of thousands of local tourists to national parks now. In other words, state investments and the activity of the private sector are among the main factors in the development of green tourism.

As for transport infrastructure, several new international flight routes were opened in the late 2010s. In 2017, the Baku-Tbilisi-Kars railway was put into operation, which increased the possibilities of traveling to the region by land . During that period, Baku began to become the aviation hub of the region with initiatives such as the BAKU Travel Hub. If we look at how foreign tourists arrived in Azerbaijan, in 2017, 42.7% were recorded arriving by plane, 40.4% by road, and 11.4% by rail. Sea transport was used sparingly. These statistics have been approximately similar in recent years. This leads to the conclusion that the quality of air and road transport directly affects the flow of tourism. For example, after the pandemic, a number of international flights (for example, direct flights from Baku to Milan, Seoul, Lahore, Sharm el-Sheikh, etc.) were restored in 2022-2023, and new ones were opened . This also had a positive impact on tourist dynamics .

Result. Finally, human resources and organizational factors are also important in the formation of green tourism. At the beginning of 2020, the Ecotourism Association was established for the first time in Azerbaijan . This non-governmental organization aims to promote the development of ecological culture and ecotourism. Established in January 2020, the Association brought together local experts in cooperation with organizations such as WWF and TIES (International Ecotourism Society). Samir Dubendi, chairman of the association, noted that the goal is to bring Azerbaijan to a leading position among sustainable tourism countries. Such initiatives have increased awareness in the field of green tourism and brought a professional approach to the sector. At the same time, cooperation between institutions such as the Ministry of Ecology and Natural Resources and the State Tourism Agency has strengthened. For example, since 2019, the creation of eco-corridors in Shahdag National Park has begun as a joint project of the MENR and the Regional Ecology Center [. Within this framework, an ecotourism program was developed together with communities, eco-trails were laid, and infrastructure was created. This model, which was tested in Shahdag, was planned to be applied to other national parks.

Thus, if we summarize the main factors shaping the development dynamics of Azerbaijani green tourism, they are: (1) Strategic support of the state and the declaration of the sector as a priority (legislation, programs), (2) Infrastructure investments (hotels, roads, service network), (3) Visa regime and promotion of the country's brand (image campaigns), (4) Changes in demand in local and foreign markets (global trend towards ecotourism), (5) The inclusion of new territories in the tourism cycle (the potential associated with the liberation of Karabakh - this issue will be addressed in Chapter 2.2), and (6) Human resources and institutional development (associations, trainings). As a result of the synergy of these factors with each other, especially starting from 2022, Azerbaijani green tourism is entering a new qualitative stage. In the next sub-chapter, we will analyze the country's green tourism potential - that is, its existing resources and capabilities.

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DIGITAL TECHNOLOGY TRANSFORMATION AND CHANGING TOURIST BEHAVIOR IN TOURISM

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Abstract
The article analyzes the growing role of digital technologies in the tourism industry and their impact on tourist behavior. The impact of virtual reality (VR), augmented and mixed reality (AR/MR), immersive environments, and digital reconstruction mechanisms on tourist perception, decision-making processes, and motivation for choosing destinations is highlighted. The theoretical foundations of re-experiencing objects with limited physical presence or subject to degradation in digital format are also revealed. Along with the practical potential of the digital transformation process in the tourism sector of Uzbekistan, risks and barriers related to technological, financial, personnel, and user acceptance are briefly analyzed. The research results show that immersive technologies are of strategic importance in tourism marketing, cultural heritage preservation, and the creation of new tourist consumption formats.

Keywords: digital technologies in tourism; immersive environments; virtual reality; augmented reality; digital reconstruction; tourist behavior; digital transformation; cultural heritage preservation.

Introduction. In recent years, the tourism industry has been undergoing a period of dramatic change. The rapid development of digital technologies, on the one hand, is changing the behavior and expectations of tourists, and on the other hand, it is forcing a fundamental rethinking of the content, form and presentation of tourism products. Virtual reality (VR), augmented and mixed reality (AR/MR), mobile applications and web platforms have become one of the main factors shaping the tourist experience. This process is closely related to the digital transformation of tourism, creating new opportunities for destination marketing, cultural heritage preservation, tourist decision-making, and increasing the economic efficiency of tourism (Buhalis & Law, 2008; Pantano & Servidio, 2009).

As travelers increasingly seek personalized, immersive, and digitally enhanced experiences, tourism providers are embracing innovation to remain competitive in a dynamic global marketplace(Toirova, 2025). Digital innovations are becoming particularly relevant in two areas. First, the rise of digital tools that support the pre-trip decision-making process: "pre-experience" of a destination through VR and digital environments has a significant impact on tourists' perceptions, motivations and expectations. Second, new forms of preserving cultural heritage and protecting deteriorating sites. As some historical and natural sites are being destroyed by overtourism or natural disasters, AR/VR technologies are making it possible to virtually recreate them, digitally preserve them and reintroduce them into tourist consumption (Bec et al., 2019; Guttentag, 2010).

In this process, the scientific literature is increasingly introducing the approach of digitally recreating objects that have been degraded or have limited physical presence. This approach involves reviving objects that existed in the past but that can no longer be experienced in real life for various reasons through digital platforms (Han et al., 2019). Digital restoration not only reduces tourism pressure, but also allows for the preservation of destroyed or endangered destinations as informational and educational value (Guttentag, 2010).

This article examines the theoretical state of integration of VR, immersive environments, and the interaction between them in modern tourism. The aim of the article is to conceptually demonstrate the impact of advanced digital tools on tourism processes, explain the new functions they bring to the tourism industry, and assess their future prospects. The article will also serve as a basis for determining the practical potential of these technologies for developing tourism regions such as Uzbekistan.

Immersive technologies and changing tourist behavior

The rapid development of digital technologies is fundamentally changing the decision-making process of tourists, the perception of destinations and tourist behavior in general. In modern tourism, Virtual Reality (VR), Augmented Reality (AR), Mixed Reality (MR) and immersive environments are becoming key tools for enriching the tourist experience, shaping emotional relationships and cognitive evaluations. These technologies enhance the visual, affective and cognitive stimuli that influence the tourist's choice process, as a result of which they increase their interest in the destination and the likelihood of visiting it (Craig et al., 2009; Pantano & Servidio, 2009).

VR technologies allow tourists to explore destinations in a realistic way without physically visiting them. Research shows that the visual and multisensory experience created through VR creates a "sense of presence" in tourists and enhances their emotional responses (Brunetti & Servidio, 2009). This process strengthens the tourist's interest and trust in the object and reduces uncertainty in decision-making.

Also, virtual reconstruction of archaeological sites, historical monuments and cultural artifacts using VR helps tourists better understand the original state, function and historical context of the object (Alfano et al., 2008). This is especially important for objects that have been physically degraded or are at risk.

Pervasive environments create a digital ecosystem that combines the real and virtual worlds through the

integration of VR, sensors, camera systems, 3D graphics and multimodal interfaces (Steventon & Wright, 2010). In such environments, the tourist actively interacts with the surrounding images, objects and scenarios, which in turn changes behavior through three mechanisms: exposure, perceptual selection, interpretation.

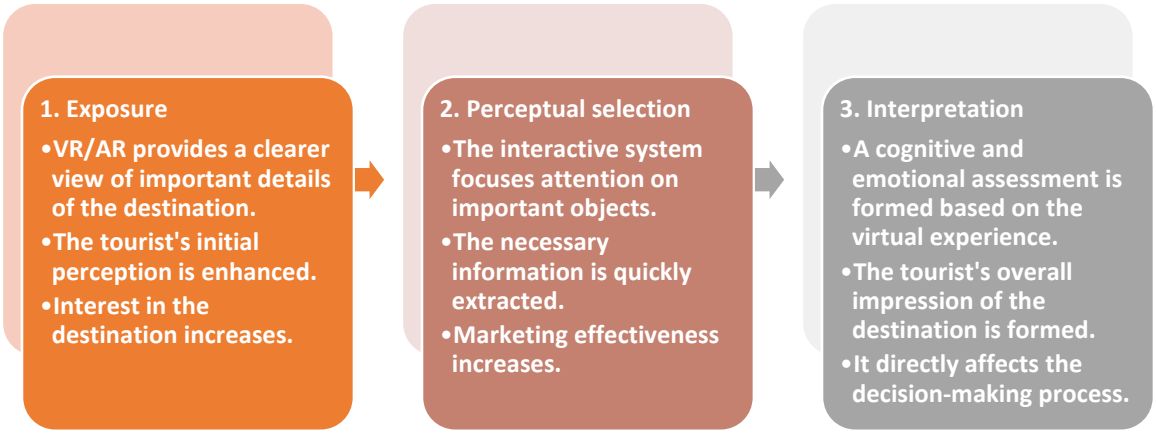

Figure 1. Mechanisms of change in tourist behavior through immersive technologies

Through these mechanisms, pervasive environments play an active role in the tourist's need perception, information search, and pre-purchase evaluation stages (Blackwell et al., 2006). Therefore, immersive systems become a powerful communication tool that enhances the emotional component of the decision-making process.

Immersive experiences created using VR/MR for destinations damaged by ecosystem degradation, overtourism, and natural changes are shaping the concept of virtual restoration (Bec et al., 2019). This approach restores destroyed or closed destinations as virtual territories, giving them a "second life." These trends have intensified in the post-pandemic era, as VR/AR is seen as a safe form of tourism that complies with social distancing requirements (Higuera-Trujillo et al., 2020).

The digital transformation process is fundamentally changing the content of the tourist experience, leading to the reshaping of the modern tourist profile. One of the main applications of personalization in the tourism industry is the development of customized travel plans. These plans include dynamic itineraries that can be adjusted in real time based on the traveler's preferences, feedback, and any changes in the situation (Xusniddinova, 2025). The modern traveler prefers highly personalized, emotionally enriched and interactive content over traditional information. Therefore, several key trends are observed in the needs of tourists: first, they increasingly demand content tailored to their personal preferences; second, they seek immersive experiences with a strong visual and emotional impact; third, they seek to reduce uncertainty and risk in the decision-making process; and finally, tourists prefer the opportunities to create their own participation in the digital environment. In addition, VR/AR technologies have the potential to form an altruistic attitude towards certain historical, cultural or environmental objects. Tourists who see the processes of deterioration of an object or its previous state in a virtual environment are strengthened in the understanding of the need to preserve it. This, as H. Park noted, is very important to study tourism opportunities that allow for economic development and reflect social and cultural needs, taking into account the economic and socio-cultural significance of unique places (Park, 2010).

In general, immersive technologies are shaping a new phase of tourist behavior in line with the semantic complexity of tourist needs and creating important strategic opportunities for modern tourism marketing.

Theoretical foundations for digital reconstruction and re-experiencing of disappearing destinations.

The rapid development of digital technologies is creating the opportunity to recreate, in addition to traditional forms of tourism, objects that do not exist physically or are severely degraded, as virtual re-experiences. The theoretical foundation of this process is based on several areas: digital heritage preservation, immersive education, sensory experience design, and cognitive-emotional mechanisms of tourist behavior.

First, 3D laser scanning, photogrammetry, and computer graphics allow for high-resolution digital reconstruction of historical objects (Guttentag, 2010; Little, 2017). Such technologies recreate ancient monuments, archaeological sites, and natural landscapes in virtual form, bringing knowledge about them to a wide audience, and reducing their risk of extinction.

Second, immersive environments based on VR and AR, while not fully replace a physical visit, offer a meaningful and emotionally enriched representation of

a tourist site (Bec et al., 2019). This approach is especially important for areas with limited physical access, at risk, or closed. Through virtual representations, tourists can imagine the reconstruction, historical form, or lost elements of the site.

Third, reconstructions created through immersive technologies provide tourists with not only information, but also an emotional connection. Studies show that virtual experiences increase the user's satisfaction with the site, interest, and desire to protect it (Park, 2010; Tussyadiah et al., 2018). Therefore, such experiences increase the perception of heritage sites as valuable.

Fourth, digital reconstruction can also play an important role in managing tourism flows. Virtual experiences offered through VR/AR can reduce the burden on places that are under excessive visitor pressure, as some tourists may choose the digital experience or use it as a preparation for a physical visit. This slows down the degradation process of cultural sites.

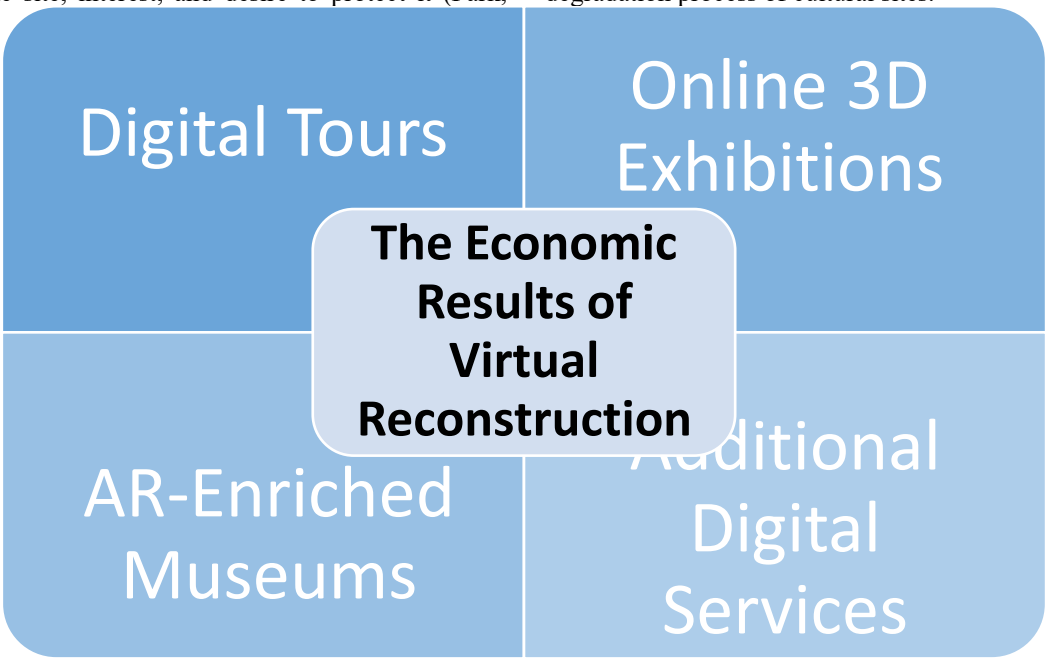

Figure 2. A new model of economic opportunities based on virtual reconstruction.

In this regard, digital restoration and the creation of immersive experiences are shaping new consumption formats in the tourism industry that are not dependent on the physical presence of the destination. This approach not only performs the function of preservation, but also offers tourist heritage in an accessible, convenient and safe form for more people.

Risks and barriers to the introduction of digital technologies in the tourism industry of Uzbekistan.

The process of introducing immersive technologies, virtual reconstruction and digital services in the tourism sector of Uzbekistan is limited by a number of systemic risks and barriers. Identifying these risk factors is important for ensuring the sustainability of technological transformation, increasing investment efficiency and creating services that meet user needs.

Technological risks. The insufficient development of digital infrastructure is manifested as the main technological risk.

– Lack of high-speed Internet in many museums and archaeological sites;
– Limited availability of 3D scanning, VR cameras and AR devices;
– Software instability or rapid obsolescence.

These situations directly affect the quality of immersive experiences and create a mismatch between the results expected by tourists and practice.

Financial risks. Creating and constantly updating digital content requires significant investments.

– High initial costs of VR/AR projects;
– Incomplete formation of monetization mechanisms;
– Risk aversion of private investors

As a result of financial risks, many projects are tied to short-term grants, which limits their sustainable development.

Staffing barriers. There is a lack of local experts in digital heritage, 3D modeling and immersive design.

– Few VR/AR developers requiring specialized skills;
– Insufficient cooperation between historians and technologists in the content creation process;
– Training programs are developing slowly

This obstacle negatively affects the quality of technological projects and their practical results.

User experience and adoption risks. The implementation of digital technologies is associated not only with technical, but also with social acceptance factors.

– VR dizziness or discomfort in older users;
– Unevenness of the level of digital literacy across regions;
– Lack of trust in new technologies

These risks slow down the mass adoption of immersive services.

Although the potential for digital transformation in Uzbek tourism is high, existing risks and barriers may hinder the full implementation of technologies. A strategic approach, a sustainable investment model, the

training of qualified personnel, and the formation of legal standards are the main conditions for minimizing these risks.

Conclusion. Digital technologies are fundamentally changing the tourism industry, significantly reshaping tourist behavior, decision-making processes, and perception mechanisms of the tourist experience. VR, AR, and immersive environments allow tourists to realistically preview destinations, create emotional connections, and reduce uncertainty. Such technologies not only increase tourist interest, but also expand the possibilities of preserving cultural heritage and presenting it in new educational and aesthetic formats.

Digital reconstruction technologies play an important role in making historical and natural objects accessible to the general public and reducing degradation by creating digital copies of them. Immersive experiences, on the other hand, allow objects with limited physical presence to be re-used as new tourist content.

Although the potential for digital transformation is high in the context of Uzbekistan, factors such as infrastructure, staff training, financing, and user acceptance are emerging as serious obstacles. At the same time, with the right strategic approach and investment mechanisms, immersive technologies can help increase the competitiveness of national tourism, promote heritage sites, and create new economic opportunities. In general, digital innovations will become the main driver of the future development of tourism, playing an important role in shaping a sustainable, innovative, and globally competitive tourism ecosystem.

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A MIDDLE POWER ECONOMIC PARTNERSHIP: A NEW MODEL OF ROK-CENTRAL ASIA COOPERATION IN THE C5+1 FRAMEWORK

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Abstract

Today, global economic relations are undergoing a noticeable shift as the international system becomes increasingly fragmented and unpredictable. Institutions that previously coordinated global trade and financial flows no longer provide the same level of stability, while supply chains, investment channels and trade policies are gradually reorienting toward regional formats. As universal models of globalization weaken, countries are turning to selective partnerships and diversified regional cooperation. These changes are particularly visible in Central Asia, a region strategically positioned along major Eurasian transport corridors and deeply affected by the restructuring of global production networks.

In particular, South Korea's growing engagement with the region reflects these wider transformations. Rather than acting as a dominant power, Seoul positions itself as a technologically advanced and economically reliable partner. Its policies focus on industrial modernization, digital transformation, human-capital development and investment in strategic sectors. For the Central Asian states, these areas align closely with national development agendas centered on economic diversification, upgrading of production capacities and reducing overdependence on traditional partners.

Within this context, the Korea–Central Asia C5+1 platform has gradually evolved into a structured mechanism for cooperation. It provides a space for aligning development priorities, coordinating infrastructure projects, expanding trade and investment, and supporting the region's broader integration into global supply chains. While Central Asia offers South Korea access to critical minerals, resource bases and new markets, Korea in turn contributes technology, expertise, capital and institutional support for industrial transformation.

Given these dynamics, this article examines the economic foundations of the ROK–Central Asia partnership. It explores current trade patterns, trends in foreign direct investment, sector-specific cooperation and the role of major Korean companies in advancing structural transformation across the region. The study also assesses how economic interaction is shaped by broader regional processes, including diversification efforts, connectivity initiatives and ongoing shifts in the global economic landscape.

Keywords: Central Asia, Republic of Korea, regional integration, C5+1, economic statecraft, geopolitics, middle power diplomacy.

1. Comparative Economic Overview of Central Asian States

Table 1:

Economic breakdown of major domains of ROK-Central Asia partnership

Country	GDP 2024 / Growth	Key Resources / Resource Base	Bilateral Trade & Korean FDI (Major Sectors)	Major Korean Projects / Firms Present	Local Economic Effects & Reception
Kazakhstan	US$274.3 bn / 4.8%	Oil, gas, uranium, copper, gold, coal, iron	Bilateral trade ~US$6B (2023); Korean FDI >US$10.8B; Energy, automotive, mining, green energy, IT	KIA (auto), Doosan Enerbility (power), YPP (hydrogen/renewables), SK Ecoplant & KIGAM (critical minerals), BAKAD consortium	Job creation, tech transfer, industrial modernization; positive local reception; challenges: bureaucracy, supplier capacity

Uzbekistan	US$95.2 bn / 6.5%	Gold, uranium, copper, natural gas, cotton	Trade ~US$1.2B; Korean FDI moderate; automotive, electronics, IT, mining	Hyundai assembly, energy projects, IT/electronics ventures	Employment growth in urban areas, tech transfer in automotive and energy; positive reception but regulatory hurdles
Kyrgyzstan	US$9.5 bn / 4.1%	Gold, rare earths, hydropower	Small trade volume; Korean FDI mainly in mining	Korean mining exploration & small infrastructure projects	Limited local impact; positive perception in mining and tech; logistical constraints
Tajikistan	US$10.1 bn / 4.5%	Aluminum, hydropower	Very limited trade; FDI mainly in energy	Small-scale renewable energy projects	Some employment, skills development; positive but scale limited
Turkmenistan	US$10.1 bn / 4.5%	Natural gas, oil, cotton	Trade limited; Korean FDI focused on energy	Korean involvement in gas field technology	High-value technical projects; limited workforce effect; cautiously positive reception

1.1 Kazakhstan

Economic Overview

Kazakhstan maintained steady economic momentum in 2024, posting GDP growth of 4.8% supported by firm household consumption and investment activity. Retail turnover increased by 9.1% in real terms, exceeding the previous year's pace, partly due to a notable expansion of consumer lending and modest gains in real incomes. Investment also grew, rising by 7.5% in real terms, with the construction and housing sectors playing a central role. At the same time, foreign direct investment inflows weakened, tempering overall capital formation.

On the production side, industry expanded by 2.8%—a slower rate compared to 2023—largely due to reduced oil output, which contracted by 2.7%. The services sector remained the main contributor to growth, increasing by 4.7%. Labor-market conditions held stable, with unemployment at 4.6%, while a 21% increase in the minimum wage helped reduce poverty levels to about 7% (measured at $6.85/day).

Inflation dynamics were mixed. While consumer price growth eased to 8.6% by the end of 2024, utility tariff adjustments pushed inflation to 9.4% in early 2025, well above the National Bank's 5% target. In response, the policy rate was raised to 16.5% in March 2025. The current account deficit narrowed significantly—from 3.3% of GDP in 2023 to 1.5% in 2024—mainly due to reduced profit repatriation by foreign investors. National Bank reserves reached $45.8 billion, equivalent to roughly seven months of imports. The tenge depreciated by 13.5% in 2024 but partially strengthened in early 2025.

Fiscal conditions shifted toward expansion. The budget deficit widened to 3.7% of GDP, reflecting weaker oil revenues. Government debt rose to 23.7% of GDP, while debt-service costs reached a historic 1.6% of GDP. Credit growth remained robust: real bank lending expanded by nearly 12%, driven primarily by households. The household debt-to-wage ratio climbed to 49%, surpassing levels observed during the 2008–09 financial crisis. The banking sector recorded exceptionally strong profitability, with return on equity reaching 32.8% in 2024.

Resource Base

Kazakhstan's economy continues to rely on a large and diversified resource endowment. In 2024, the country produced 87.7 million tons of oil and 59 billion cubic meters of gas. Refining volumes reached 17.9 million tons, and petroleum-product output totaled 14.5 million tons. Oil exports amounted to 68.6 million tons, shipped primarily via pipelines and rail.

Kazakhstan remains the world's leading uranium producer, with output of 23.27 thousand tons and approximately 21% of global reserves. The country also holds considerable deposits of copper (notably in Zhezkazgan), gold (around 300 known sites, with East Kazakhstan accounting for more than one-third of reserves), coal (33.6 billion tons), lead, zinc and iron ore (16.6 billion tons). This resource foundation supports national industrialization efforts and reinforces Kazakhstan's strategic importance to regional and global markets.

Bilateral Trade and Investment with the Republic of Korea

Kazakhstan is South Korea's key economic partner in Central Asia, combining extensive resource potential with opportunities for technological upgrading. Bilateral trade reached approximately USD 6 billion in 2023. Kazakhstan's exports to Korea consist mainly of crude oil, iron, steel and ferrous metals, while imports from Korea include electronics, machinery, automotive components and finished automobiles. More than 700 Korean-affiliated joint ventures operate in the country, and cumulative Korean investment since 2005 has exceeded USD 9.4 billion.

Cooperation is gradually moving from raw-material exports toward more complex value-added sectors. Priority areas include energy and critical minerals—such as lithium, cobalt, nickel and rare-earth elements—automotive manufacturing, renewable energy, smart agriculture, IT, pharmaceuticals and water-resource management. Recent agreements emphasize joint exploration and processing of

minerals, the production of advanced equipment for the oil and gas sector, and the localization of manufacturing.

For South Korea, Kazakhstan offers a reliable source of minerals essential for semiconductor, electric-vehicle and green-energy industries, helping diversify supply chains beyond China. For Kazakhstan, Korean technology and capital support the development of processing facilities, industrial clusters and infrastructure, aiding its long-term diversification strategy.

Collaboration extends to large manufacturing facilities, including KIA and Hyundai automotive plants, and emerging segments such as battery production and hydrogen technologies. Additional joint projects cover waste management, elevator production, aviation connectivity and green-energy development. Regular high-level meetings and specialized working groups ensure continuity and coordination, signaling a long-term strategic partnership.

Major Korean Projects and Firms in Kazakhstan

South Korea's economic presence in Kazakhstan is anchored by several leading companies engaged in priority sectors such as industrial production, power generation, renewable hydrogen, critical-mineral processing and large-scale transport infrastructure. These firms play a decisive role in introducing advanced technologies, developing local manufacturing capacity and integrating Kazakhstan into global supply chains.

The five companies highlighted in the cooperation framework represent the core strategic directions of bilateral engagement. KIA and Doosan Enerbility contribute to Kazakhstan's industrial and energy modernization, while YPP Corporation advances cooperation in green hydrogen and renewable-energy solutions. SK Ecoplant and KIGAM support the creation of mineral-processing and battery-supply chains, linking Kazakhstan to global high-tech industries. The BAKAD consortium demonstrates the potential of public–private partnerships in delivering major infrastructure projects that enhance regional connectivity.

Together, these initiatives illustrate a transition from traditional trade relations to deeper industrial cooperation and long-term technological partnership.

1.2 Uzbekistan

Economic Overview

Uzbekistan continued to demonstrate strong economic performance in 2024–2025, although official statistics and international assessments differ somewhat. According to national data, GDP expanded by roughly 6% in 2023, while IMF estimates suggest growth of 5.4% in 2024 and 5.5% in 2025. Inflation has gradually eased from previous double-digit levels, falling from about 10% in 2023 to around 9–9.5% by mid-2024. However, upcoming adjustments to energy tariffs could temporarily push inflation back toward 11–12% by the end of 2024.

Economic growth has been supported by strong fixed investment and resilient consumer demand. Retail turnover and imports have increased at a moderate pace, while household credit has expanded rapidly—exceeding 17% year-on-year by mid-2024.

Fiscal policy remains relatively tight: the 2024 budget aims for a deficit of about 4% of GDP. Remittances continue to cushion external pressures, partially compensating for a sizable current-account deficit estimated at 8–9% of GDP in 2023–2024. International reserves remain comfortable, providing coverage for nearly ten months of imports. The Uzbek sum depreciated by around 10% in 2023 but stabilized in 2024. Official unemployment stands at 4–5%, and minimum wages remain modest. Poverty levels continue to decline, reaching roughly 11% in 2023. The banking sector has expanded lending, especially to households, while maintaining moderate public-debt levels (about 36% of GDP). Banking profitability remains positive but relatively low, with return on assets at approximately 2–3%.

Resource Base

Uzbekistan benefits from a wide range of mineral and energy resources that form an essential part of its economic structure. The country holds the world's fourth-largest natural gas reserves and significant oil and coal deposits. In 2024, gas production reached approximately 44.6 billion cubic meters, with proven gas reserves estimated at nearly 2 trillion cubic meters.

The country is also among the world's leading gold producers, ranking tenth in 2023 with an output of 119.6 tons. The bulk of production comes from the Muruntau and Navoi deposits, with total national gold reserves estimated at over 2,200 tons. Uzbekistan possesses notable deposits of copper, silver and rare-earth elements, further strengthening its mineral base.

Uranium is another strategic resource: Uzbekistan ranks fifth globally with assured reserves of about 40,200 tons. Hydropower potential is substantial, second only to Russia within the CIS. Major hydropower facilities include Nurek (2.7 GW) and Sangtuda (0.6 GW), while the Rogun dam (3.6 GW) is under active development. Agriculture remains a major economic sector, with leading outputs including cotton (about 1.5 million tons annually), wheat, fruit and vegetables. Export performance in early 2025 was strong, driven by rising shipments of gold, uranium, agricultural goods and services.

Bilateral Trade and Investment with the Republic of Korea

South Korea has emerged as one of Uzbekistan's key economic partners, ranking fifth among its largest trade partners. Annual bilateral trade surpasses USD 2 billion. Uzbekistan primarily exports textiles, agricultural products and services, while imports from Korea consist largely of vehicles, machinery and electronics. Korean foreign direct investment in Uzbekistan has exceeded USD 7.5 billion.

Economic cooperation spans several strategic sectors: energy, oil and gas pipelines, electric-power infrastructure, transportation, chemicals and manufacturing. Korean investments support modernization efforts, infrastructure upgrades and the expansion of industrial capacity.

Major Korean Projects and Firms in Uzbekistan

More than sixty investment projects involving Korean companies—valued at around USD 8.8 billion—are being implemented across energy, infrastructure, manufacturing and technology sectors. Key initiatives include the modernization of the Tashkent subway, development of high-speed rail systems by Hyundai Rotem, and various urban transit and road-construction projects. Renewable-energy collaboration is expanding as well, with Korean firms investing in solar-power facilities and green-hydrogen initiatives.

In manufacturing, Korean companies have helped establish localized production of KIA vehicles and contributed to the development of textile factories through joint ventures. The chemical and pharmaceutical sectors have also attracted significant Korean investment, exemplified by projects such as the Surgil fertilizer complex and emerging medical-technology clusters. Many initiatives are being advanced within the broader "K-Silk Road" cooperation framework.

Local Economic Effects and Public Reception

Korean investments have generated substantial employment and facilitated technology transfer in Uzbekistan. Automotive and textile manufacturing plants employ thousands of workers and provide technical training. Localization requirements incorporated into many projects have stimulated the growth of domestic suppliers and supporting industries.

Public perceptions of Korean companies are largely positive. Their involvement in energy, transport and industrial modernization is widely recognized, and renewable-energy projects—particularly solar power—incorporate technology-transfer components that deepen local integration and expertise.

Short-Term Outlook (2025–2026)

Uzbekistan's macroeconomic outlook remains broadly favorable. GDP growth is projected to reach around 6.5% in 2025–2026, while inflation is expected to ease gradually to 9–10% by late 2025 and move closer to single digits in 2026. Key risks include volatility in global commodity markets and inflationary pressures associated with energy-sector reforms.

Policy priorities for the coming years include fiscal consolidation, greater exchange-rate flexibility and continued structural reforms. Investment is expected to be supported by stronger China–Uzbekistan cooperation and participation in regional development initiatives. Macroeconomic stability and private-sector expansion remain central to the government's economic agenda.

1.3. Kyrgyzstan

Economic Overview

After a strong post-pandemic rebound, Kyrgyzstan's economy has shifted to a more moderate growth trajectory. GDP expanded by about 6.2% in 2023, driven mainly by investment activity, while forecasts for 2024–2025 suggest slower but stable growth. The Asian Development Bank expects GDP to rise by 4.5% in 2024 and 5.8% in 2025, whereas the IMF projects 4.4% and 4.2% respectively. Inflation has eased considerably—from 14.7% at the end of 2022 to 7.3% in late 2023—and remained within the 5–6% range in early 2024.

Remittances, amounting to more than 20% of GDP, continue to support domestic consumption but their recent decline has widened the current account deficit. Fiscal conditions are improving, with the consolidated deficit reduced to roughly 4–5% of GDP thanks to higher revenues from mining and trade. International reserves remain modest yet adequate, and the som has been stable throughout 2024. Official unemployment is below 5%, though underemployment, especially in rural areas, remains widespread. Poverty levels have declined to around 25.7% in 2024. Bank lending has grown at a decelerating pace of around 17% year-on-year as of mid-2024. Public debt has fallen to about 50% of GDP, which is considered a manageable level by international institutions.

Resource Base

Kyrgyzstan's resource sector is dominated by gold mining, with the Kumtor mine serving as the country's flagship operation. The country's confirmed gold reserves amount to roughly 973 tons as of 2025, and output reached around 17 tons between January and September 2025. Kyrgyzstan also holds copper reserves of about 960,000 tons and produced 2.3 million tons of coal in the first nine months of 2025. Oil and gas resources are limited, with gas production of 18.9 million cubic meters over the same period. Hydropower capacity remains underdeveloped, concentrated in a series of small-scale facilities. The country also possesses minor reserves of rare earth elements and other nonferrous metals. Agriculture—including cotton—plays a smaller economic role but remains vital for rural employment.

Bilateral Trade and Investment with the Republic of Korea

Economic ties between Kyrgyzstan and South Korea remain modest compared to other regional partners but show gradual expansion. In 2023, South Korean exports to Kyrgyzstan reached approximately USD 1.17 billion, mainly consisting of vehicles and machinery. By contrast, Kyrgyz exports to Korea were minimal—around USD 2.2 million—primarily agricultural niche goods such as honey and fruit. Korea accounts for nearly 80% of Kyrgyz imports sourced from the country, but its overall FDI footprint remains small, and Korea is not considered among Kyrgyzstan's major foreign investors. Most bilateral interaction continues to focus on trade and limited business cooperation.

Major Korean Projects and Firms in Kyrgyzstan

Korean investment activity in Kyrgyzstan is relatively small in scale. Reports from 2025 highlight Korean interest in construction materials, manufacturing and power-sector projects, though no major investment comparable to Uzbekistan's large-scale initiatives has been implemented. Most joint ventures are small or remain at the planning and feasibility-study stage. Discussions have included potential participation in building-material factories,

construction-related industries and small hydropower plants.

Historically, Samsung operated a manufacturing facility in Bishkek between 2019 and 2022, employing several thousand workers, but the plant was closed due to regulatory changes. Korean companies retain interest in concrete, steel manufacturing and micro-hydropower, although most initiatives remain preliminary.

Local Economic Effects and Public Reception

Given the limited Korean business presence, the overall economic impact on Kyrgyzstan remains small. The former Samsung factory provided employment and skills training, but its closure reduced ongoing benefits. Imports of Korean vehicles and electronics have supported jobs in repair and after-sales services, but technology transfer remains constrained due to the lack of major active investment projects. Public attitudes toward Korean companies are generally positive, largely due to Korea's reputation for technological quality, although the domestic market continues to be dominated by Chinese and Russian firms.

Short-Term Outlook (2025–2026)

Growth prospects for 2025–2026 remain broadly stable, with GDP projected to expand by 4–6%. Inflation is expected to remain in the mid-single digits. Key risks include external shocks—particularly changes in remittance inflows—and fluctuations in Russian demand. Domestic uncertainties in the mining sector also pose potential challenges. Public investment, including Chinese-funded infrastructure projects, will continue to influence the growth outlook. Fiscal and monetary policy is anticipated to remain conservative, with a focus on debt reduction and financial-sector stability.

1.4 Tajikistan

Economic Overview

Tajikistan has maintained strong economic growth over the past several years, with GDP rising by approximately 8–8.5% in 2023–2024. Growth has been fueled by expanding services, increased trade activity and construction. Inflation has remained low—around 3–4% in 2024—reflecting tight monetary policy and active price controls. The fiscal deficit has been kept near 2.5% of GDP, and public debt remains relatively modest at around 25% by late 2024.

Remittances remain the backbone of Tajikistan's economy, accounting for 30–35% of GDP, and continue to support consumption and offset structural weaknesses. The current account has generally recorded a slight surplus, aided by remittance inflows and foreign assistance. International reserves cover roughly seven months of imports, and the somoni has remained stable. Official unemployment stands at around 2%, though underemployment in rural areas remains significant. Poverty levels have declined to about 20%. Bank lending is expanding, and improvements in the financial sector have helped maintain low inflation.

Resource Base

Tajikistan's natural-resource capacity is concentrated in hydropower, mining and agriculture. The country has some of the world's most significant hydropower potential, ranking among the top ten globally. Existing facilities—including the Nurek (2.7 GW) and Sangtuda (0.6 GW) plants—generate around 17 billion kWh annually. Construction of the Rogun dam (3.6 GW) is expected to further enhance the country's generation capacity.

Agriculture continues to play an important role, with cotton production reaching approximately 400,000 tonnes annually. Tajikistan also produces around 300,000 tons of aluminum each year through the Talco plant. Gold, silver, lead and zinc deposits exist but contribute modestly to the broader economy. While water resources are abundant, the country has only limited oil and gas reserves.

Bilateral Trade and Investment with the Republic of Korea

South Korea's economic presence in Tajikistan remains limited. Bilateral trade is minimal, and South Korea is not among the country's key export or investment partners. Korean FDI remains small, and cooperation is mainly limited to exploratory discussions and diplomatic initiatives.

Major Korean Projects and Firms in Tajikistan

Tajikistan lacks large-scale Korean investments comparable to those in Uzbekistan or Turkmenistan. Some Korean firms have shown interest in mining, energy feasibility studies and infrastructure assessments, but no major projects have been implemented to date. Occasional discussions have explored potential cooperation in renewable energy and small and medium enterprise development, but these initiatives remain at the planning stage.

Local Economic Effects and Public Reception

Because Korean investment in Tajikistan is minimal, its economic effects are negligible. There has been no substantial job creation, industrial development or technology transfer linked to Korean firms. Cultural and educational exchanges—including language programs and scholarships—exist but have only a limited economic impact. Overall, Korea's presence has not significantly shaped Tajikistan's economic or industrial landscape.

Short-Term Outlook (2025–2026)

Tajikistan is expected to maintain solid economic growth of 6–7% annually over the next two years. Inflation is projected to remain low at around 4–6%. However, the economy remains highly dependent on remittances, making it vulnerable to regional shocks. Hydropower output may fluctuate due to drought risk, posing an additional challenge. Policy priorities include improving governance, diversifying exports beyond metals and cotton and expanding employment opportunities. Continued prudent fiscal policy and stable macroeconomic management will be essential for sustaining the positive outlook.

1.5. Turkmenistan

Economic Overview

Turkmenistan's economy continues to rely overwhelmingly on hydrocarbons and large state-led investment programs. In 2024, real GDP was estimated at around USD 82.5 billion, marking an annual growth rate of roughly 6%. Inflation remained exceptionally low by regional standards, falling from about 3.8% at

the end of 2024 to nearly 1.1% in early 2025. The current account surplus narrowed slightly—from 5.9% of GDP in 2023 to 4.4% in 2024—reflecting softer external demand. Public debt remains minimal at approximately 3.6% of GDP.

Official unemployment is reported near zero, though underemployment persists due to the dominant role of the state sector and limited private-sector development. Growth projections for 2025 suggest a more moderate expansion of about 2.3%, with downside risks tied to global energy-market volatility and structural constraints within the domestic economy.

Resource Base

Turkmenistan holds one of the largest natural gas reserves in the world—estimated at nearly 400 trillion cubic feet—placing the country among the top five globally. Dry natural gas production reached approximately 3.0 Tcf in 2023, the highest recorded output to date. Oil production and refining activities also contribute significantly, although detailed data are publicly limited. Additional natural resources include coal, sulfur and several smaller mineral deposits.

The country's resource base is thus heavily concentrated in hydrocarbons, particularly natural gas and petrochemicals. As a result, Turkmenistan remains highly susceptible to shifts in global energy prices and demand, underscoring the importance of diversification efforts.

Bilateral Trade and Investment with South Korea

Despite Turkmenistan's substantial energy reserves, direct trade volumes with South Korea remain relatively modest. However, Korean companies have secured important project contracts in the country's energy and industrial sectors. Over the past decade, the cumulative value of Korean-awarded projects in Turkmenistan has reached approximately USD 5 billion.

In 2024, both countries signed a Trade and Investment Promotion Framework (TIPF), establishing a formal basis for cooperation in energy development, infrastructure projects and industrial modernization. This agreement provides clearer institutional structure for expanding business engagement.

Major Korean Projects and Firms in Turkmenistan

South Korean firms operate in several strategic sectors of Turkmenistan's economy. Hyundai Engineering has partnered with Turkmengaz to develop a desulphurization facility at the Galkynysh gas field—one of the world's largest gas deposits. Korean companies also participate in the Kiyanly Polymer Plant, which produces polyethylene and polypropylene, and assist in upgrading the Turkmenbashi oil refinery complex.

Shipbuilding cooperation is another notable area. Through the Balkan Shipbuilding and Repair Plant, Korean partners—including Koryo Shipbuilding Industry Technology Co.—support the construction of dry-cargo vessels and related industrial capabilities. In total, around fourteen Korean projects are currently reported in Turkmenistan, with combined values exceeding USD 11 billion.

Local Economic Effects and Public Reception

Korean-led projects offer potential benefits in the form of technology transfer, skilled employment and industrial upgrading, particularly in petrochemicals, shipbuilding and large-scale infrastructure. Public perception of Korean firms remains favorable, largely due to their technical expertise and consistent long-term engagement.

However, the broader developmental impact remains limited. Turkmenistan's tightly controlled state-led economic model restricts the formation of local supplier networks and constrains private-sector participation. Heavy reliance on imported equipment and the dominance of state enterprises reduces opportunities for widespread spillover effects.

Short-Term Outlook (2025–2026)

The medium-term outlook for Turkmenistan is one of cautious stability. GDP growth is expected to hover around 2–3% in 2025, with potential upside if diversification initiatives advance or new gas-export infrastructure becomes operational. Inflation is projected to rise gradually toward historical averages of around 8%, driven by planned increases in wages and pensions.

Fiscal indicators remain strong, but major risks stem from dependence on hydrocarbon prices, limited economic diversification and an overvalued real exchange rate. If Korean and other foreign investment projects proceed according to plans, non-hydrocarbon sectors could contribute more substantially to growth. Nonetheless, structural transformation is still in an early phase.

1.6 Verdict

South Korea has become an important source of technology, investment and industrial modernization for the economies of Central Asia. Korean projects support diversification, infrastructure development, energy modernization and integration into global value chains, while also facilitating knowledge transfer and productivity growth across key sectors.

For Korea, Central Asia holds growing strategic value as a supplier of essential resources—including oil, natural gas, uranium, copper and rare earth elements—and as a dynamic market for industrial cooperation and innovation-driven projects. This complementarity forms a strong basis for long-term partnership focused on technological advancement, energy transition and strengthened economic resilience on both sides.

2. Trade, Investment, and Development Cooperation Between South Korea and Central Asia

2.1. Aggregate trade patterns and sectoral composition

Table 2.

ROK exports to Central Asia, 2013 and 2024 (USD). Source: United Nations Commodity Trade Statistics

Year	Kazakhstan	Uzbekistan	Turkmenistan	Kyrgyzstan	Tajikistan	Total CA

2013	$1,074,499,330	$1,968,036,458	$141,188,955	$163,907,226	$44,299,399	$3,391,931,368
2024	$2,345,104,720	$1,719,861,596	$56,825,386	$1,785,814,982	$188,906,695	$6,096,513,379

Table 3.

Central Asia exports to the Republic of Korea, 2013 and 2024 (USD). Source: United Nations Commodity Trade Statistics

Year	Kazakhstan	Uzbekistan	Turkmeni-stan	Kyrgyzstan	Tajikistan	Total CA
2013	$128,463,201	$45,857,163	N/A	$2,251,425	$31,635	$176,603,424
2024	$1,252,455,195	$29,797,823	37,710	$2,551,222	$2,857	$1,284,844,807

The two tables illustrate how trade between the Republic of Korea and Central Asian states has evolved between 2013 and 2024, highlighting both expansion in scale and subtle structural shifts. Korean exports to the region nearly doubled—from USD 3.39 billion in 2013 to USD 6.10 billion in 2024—indicating Korea's growing commercial footprint. Kazakhstan and Uzbekistan continue to account for the majority of imports from Korea, reflecting their larger economies and more diversified industrial bases. The strongest demand remains concentrated in machinery, transport equipment, electrical goods and industrial inputs, where Korea has well-established competitive advantages.

Turkmenistan is the one outlier, showing a decline in imports from Korea over the same period. This may reflect a drop in project-based contracts or a shift toward alternative procurement partners. Smaller economies such as Kyrgyzstan and Tajikistan demonstrate steady growth in imports, though the overall volumes remain small due to market size constraints.

Central Asian exports to Korea follow a different pattern. Although the volume remains significantly lower than Korean exports to the region, total shipments increased substantially—from USD 176.6 million in 2013 to USD 1.28 billion in 2024. Kazakhstan accounts for almost the entire increase, driven by higher exports of minerals, metals and energy-related commodities. Uzbekistan contributes moderately, while Kyrgyzstan and Tajikistan export only small volumes. Turkmenistan's modest but newly measurable exports in 2024 signal a gradual broadening of trade activity.

Overall, these trends reveal two structural features of Korea–Central Asia trade. First, the trade relationship remains asymmetric: Korea exports far more to the region than it imports, reflecting the classic pattern between industrialized and resource-rich economies. Second, the growth of trade on both sides' points to a deepening economic partnership, supported by aligned interests in industrial development, resource cooperation and improved connectivity. This provides an empirical basis for understanding Korea's expanding economic diplomacy in Central Asia.

Investment Flows and Financing Mechanisms

To understand Korea's financial engagement in Central Asia, it is essential to distinguish between state-backed export-credit mechanisms and private investment. Export Credit Agencies (ECAs) and Export–Import Banks, such as the Export–Import Bank of Korea (KEXIM), provide financial instruments designed to reduce risk and support cross-border trade. These typically include buyer's and supplier's credits, export insurance, political-risk guarantees and direct loans for investment projects. Their primary function is to facilitate international sales of domestically produced goods and services.

Private capital—such as bank financing, institutional investment, private equity and foreign direct investment—operates on different principles. It responds mainly to commercial incentives, expected returns and market risk, rather than national industrial or trade policy. OECD guidance remains the main international reference for defining categories of officially supported export credits and for setting global norms in areas such as pricing, transparency and allowable tenors.

Korea's institutional architecture

KEXIM performs the dual role of an export credit agency and an administrator of concessional development finance, including the Economic Development Cooperation Fund (EDCF). Through a combination of commercial credits, concessional loans and buyer's-credit facilities, KEXIM supports Korean companies engaged in large infrastructure, energy and transport projects abroad. Its annual reports highlight frequent co-financing with multilateral institutions and risk-sharing mechanisms with private banks. This diversified toolkit strengthens Korea's ability to pursue economic diplomacy while advancing the international competitiveness of Korean firms.

Regulatory shifts and emerging risks

Officially supported export finance operates under a multilateral rules-based system, shaped primarily by the OECD Arrangement on Officially Supported Export Credits. Recent debates have broadened the framework to incorporate environmental considerations, including restrictions on financing for carbon-intensive projects. This creates direct implications for project pipelines in resource-rich regions such as Central Asia. Meanwhile, academic research highlights the risks of subsidy competition among ECAs, regulatory arbitrage and challenges in measuring concessionally and project additionality. These issues underline the importance of careful ESG assessment and transparent risk management in publicly supported finance.

Application to the Korea–Central Asia context

Three patterns stand out:

1. KEXIM and EDCF instruments are well-suited for large-scale Central Asian projects: Kazakhstan and Uzbekistan, where capital needs exceed private-sector appetite and project risks remain

high, rely significantly on such financing for energy and infrastructure development.

2. Co-financing:

Joint financing arrangements with multilateral development banks and commercial lenders increase project bankability and attract private participation by distributing risk.

3. Private-investment

Expansion into manufacturing and services depends on improvements in regulatory transparency, contract enforcement and investor protection—factors that remain uneven across the region.

The broader trade patterns—including rising Central Asian exports to Korea and the near doubling of Korean exports over 2013–2024—suggest that these financing mechanisms have strengthened commercial ties while reinforcing Korea's position as a net exporter in the region.

Infrastructure, Connectivity and Supply Chains

Infrastructure is central to shaping how firms participate in regional and global value chains. Improved transport networks reduce logistical barriers, enable more predictable delivery schedules and make geographically fragmented production feasible. Findings from gravity models show that better transport and logistics infrastructure reduces trade costs, while the supply-chain fragmentation framework demonstrates how lower service-link costs support the separation of production stages across countries. Network theory also highlights that corridor reliability, redundancy and network centrality often matter more than sheer distance in determining routing decisions.

These mechanisms are clearly visible in the evolving Eurasian transport landscape. The Middle Corridor (Trans-Caspian route) and TRACECA form the backbone of east–west multimodal transport across Central Asia and the South Caucasus. Despite their strategic potential, World Bank and TRACECA assessments identify persistent bottlenecks—ranging from limited port capacity to interoperability issues—that reduce efficiency and increase transit times. Competing northern and southern transit routes exert additional pressure on governments and logistics operators, shaping investment decisions and routing strategies.

Physical infrastructure, however, is only part of the story. Institutional and digital interoperability increasingly determine corridor competitiveness. Evidence from CAREC and TRACECA highlights the importance of single-window systems, harmonized electronic documentation (e.g., e-CMR), integrated data platforms and digital customs procedures. These tools reduce delays at border crossings, improve supply-chain visibility and create conditions for more advanced manufacturing and logistics activities. Without coordinated digital systems, fragmented regulations and manual procedures accumulate delays that disproportionately affect high-value and time-sensitive shipments.

Financing these infrastructure corridors requires a mix of public and private capital. Multilateral development banks, national EXIM agencies and central governments typically shoulder early-stage risks, while private investors enter once tariff regimes, governance structures and demand forecasts become predictable. Recent analyses also underscore the need to align transport investments with green-finance standards.

For South Korea, whose competitive strengths include engineering, capital goods and digital logistics solutions, Central Asian connectivity offers significant strategic and commercial potential. Yet Korean firms face challenges arising from inconsistent customs procedures, limited corridor reliability and gaps in institutional harmonization. Priority measures include expanding KEXIM/EDCF co-financing arrangements, investing in multimodal hubs, supporting customs digitalization and participating more actively in CAREC and TRACECA standard-setting processes.

Real-world examples illustrate these dynamics. The Baku–Tbilisi–Kars's railway shortens transit times but is constrained by capacity and hinterland connectivity. The Trans-Caspian maritime–rail interface is limited by ferry capacity, port handling efficiency and gauge changes. Digital initiatives such as e-CMR pilots demonstrate measurable improvements in border processing times. Collectively, these elements show that the future of Eurasian connectivity depends not just on infrastructure construction, but on the alignment of regulatory frameworks, digital systems and cross-border governance.

2.2 Mechanisms of Impact: Employment, Technology Transfer, and Value Chains

Foreign direct investment (FDI) and multinational enterprises (MNEs) are among the most influential forces shaping structural change in developing economies. In Central Asia, Korean industrial, automotive and electronics companies contribute to economic transformation through three well-documented channels: job creation, technology and knowledge transfer, and integration into global value chains (GVCs). Evidence from the ADB, World Bank, UNCTAD and Korean research institutions consistently highlights the importance of these mechanisms for long-term development.

Employment Creation and Labour Transformation

FDI generates employment directly—through foreign-owned plants, service centers and supplier networks—and indirectly, via increased demand for logistics, construction and subcontracting. Studies by Kalyuzhnova and Holzhacker (2021) show that improvements in connectivity and investment flows increase labor demand in manufacturing-oriented and science-intensive sectors. This trend is increasingly visible in Central Asia, where Korean firms create jobs for semi-skilled and skilled workers in automotive components, machinery, petrochemicals and electronics.

Korean investors also contribute to labor upskilling. As Saggi (2002) notes, MNEs transfer managerial practices and organizational routines that domestic firms later adopt, raising overall productivity. For Central Asian states seeking to diversify beyond

extractive industries, these training effects are especially valuable. ADB research (2021) further demonstrates that participation in regional production networks encourages labor shifts away from low-productivity agriculture toward higher-value industrial and logistics services.

Technology Transfer and Knowledge Spillovers

Technology transfer is widely viewed as the most significant long-term benefit of FDI. Korean companies introduce automation systems, energy-efficient equipment, digital logistics platforms, and modern quality-control processes. These technologies create learning opportunities for domestic firms, which gain both technical and managerial capabilities over time.

UNCTAD (2010) emphasizes that the scale of technology absorption depends on domestic "absorptive capacity"—skills, experience and financial resources within local firms. In Kazakhstan and Uzbekistan, supplier development programs, joint ventures and technical training centers implemented by Korean companies support this capacity. OECD (2023) research further notes that Korea's economic model—characterized by strong ties between large firms and specialized SMEs—is often replicated abroad, encouraging co-learning and clustering in host economies.

Integration into Global Value Chains (GVCs)

Participation in GVCs allows developing economies to specialize in specific production stages and access international markets. For Central Asia, traditionally constrained by transport costs and fragmented infrastructure, Korean investment accelerates value-chain integration. Korean firms serve as "anchor companies," importing intermediate inputs, assembling or processing them regionally, and exporting higher-value goods.

These activities generate multiple upgrading effects:

- Supplier upgrading through adoption of Korean quality and safety standards
- Process upgrading via automation and lean production
- Functional upgrading as local firms gains roles in logistics, servicing or component design
- Economic diversification through expansion into manufacturing

ADB, OECD and World Bank studies confirm that these dynamics are particularly important for resource-dependent economies such as Kazakhstan and Uzbekistan, where industrial diversification is a core policy priority.

2.3 Case Study: Korean FDI in Kazakhstan's Industrial Development

Strategic Context

Kazakhstan's industrial base has expanded steadily since the early 2000s, supported by government efforts to diversify the economy beyond hydrocarbons. Korean multinational enterprises—including POSCO, Hyundai and Daewoo—have become important contributors to this shift. Rather than focusing solely on resource extraction, Korean investors target complex manufacturing and industrial processing, aligning with Kazakhstan's long-term development goals.

World Bank analyses (2020) show that such investments modernize production, strengthen competitiveness and promote integration into regional value chains. Korean FDI therefore plays a dual role: accelerating Kazakhstan's industrialization while securing new regional footholds for Korean companies.

Investment Patterns and Motivations

According to Lee, Chernikov and Nagy (2022), Korean investment in Kazakhstan is overwhelmingly market-seeking. Firms are attracted by the country's large consumer base, industrial potential and strategic position within Central Asia. Korean MNEs prefer technologically intensive projects—vehicle assembly, industrial machinery, petrochemicals—which create long-term supply-chain linkages.

POSCO provides industrial steel inputs, while Hyundai and Daewoo contribute to automotive and machinery manufacturing. These investments often take the form of joint ventures, greenfield plants, and technology partnerships, enabling closer interaction between Korean firms and domestic suppliers.

Development Impacts

Employment:

Korean-owned production facilities and supplier networks create skilled jobs in engineering, logistics, assembly and plant operations. World Bank findings indicate that employment multipliers in industrial sectors are high, supporting both urban and semi-urban labor markets.

Technology:

Korean firms introduce advanced manufacturing systems, managerial standards and quality-control mechanisms. Training programs and joint ventures enhance technological capabilities among domestic engineers and technicians.

Value-Chain:

Kazakhstan increasingly participates in regional and global production networks through Korean-led industrial projects. Components produced locally feed into broader Central Asian and Asian supply chains.

Development Outcomes:

Korean FDI supports Kazakhstan's broader industrial-policy objectives by:

- advancing economic diversification
- raising workforce skills
- improving technological sophistication
- strengthening export and supply-chain integration

These outcomes collectively enhance Kazakhstan's industrial competitiveness and set the groundwork for sustained long-term growth.

Transparency Note

Due to the limited availability of publicly documented Korean investments specifically in grid and energy infrastructure, this case study focuses on industrial and petrochemical sectors where evidence is well established. Sources include the World Bank, OECD, and peer-reviewed studies.

2.4. Summary of Empirical Indicators for Measuring FDI Contribution to GDP

The aim of this section is to outline a transparent and replicable method for assessing the economic contribution of Korean FDI in Central Asia. The framework follows OECD (2008), UNCTAD (2010) and World Bank (2020) methodological standards.

Production-Based Indicators (GVA)

Gross Value Added (GVA) measures the direct output generated by Korean-affiliated firms. Sectoral output shares and the presence of foreign-owned firms provide insight into the scale of Korean investment.

Labour and Income Indicators

Employment created by Korean companies—both direct and through supply chains—feeds into household income. Wage spending stimulates consumption, generating additional induced contributions to GDP.

Productivity Spillovers

Technology transfer from Korean firms raises labor productivity, production efficiency and managerial quality in domestic companies. These spillovers support long-term structural change.

Trade and GVC Indicators

Korean investors deepen integration into global production networks. Indicators include export contributions, domestic value added in processing activities, and reliance on imported intermediate goods.

Multiplier Effects

FDI stimulates demand for domestic materials, logistics, construction and supporting services, amplifying economic output across sectors.

Applied Example: Kazakhstan

Using the framework above:

- Korean FDI in Kazakhstan reached USD 10.8 billion in 2024, while GDP was USD 274.3 billion**.**
- Direct GDP contribution is approximately 3.9%, and including multiplier effects, 5–6%**.**
- Employment effects stem from major firms such as Hyundai, Doosan Enerbility, YPP, SK Ecoplant, and KIGAM.
- Technology transfer is visible in automotive assembly, petrochemicals and green-energy projects.
- Trade effects include increased exports of vehicles and electronics, and improved processing of critical minerals such as lithium, cobalt and nickel.

This demonstrates that Korean FDI plays a substantive role in Kazakhstan's industrial modernization and economic diversification.

3. Comparative Analysis: Japan vs China vs Republic of Korea in Central Asia

3.1. Policy overview

Japan

Japan's engagement in Central Asia is best understood within the broader evolution of its foreign policy. By 2025, Japan had experienced a significant political shift with the election of Sanae Takaichi—its first female president—symbolizing an internal democratic milestone and a renewed outward-facing posture.

Under Takaichi, Japan continues to promote a rules-based international order, strengthening military and economic cooperation with the United States while deepening its distinct brand of economic and development diplomacy. Tokyo positions itself as a middle power that balances deterrence toward China with pragmatic economic engagement, coupled with selective cooperation with the Republic of Korea. Japan's external toolkit relies heavily on non-military instruments: Official Development Assistance (ODA), climate initiatives, technology partnerships, and institutional capacity-building, reflecting constitutional limits on the use of force.

Japan presents itself as a responsible and peace-oriented actor able to deliver high standards, transparency, and long-term sustainability.

In Central Asia, Japan's strategy is driven by three core objectives:

1. Balancing China's Belt and Road Initiative (BRI) by providing an alternative partner and countering overdependence on Chinese corridors.
2. Supporting states seeking diversified partnerships and reducing excessive reliance on Russia.
3. Enhancing Japan's energy and resource security, particularly uranium, rare earths, oil, and natural gas from Kazakhstan and Turkmenistan.

By engaging Central Asia, Japan aims to secure stable supplies of critical minerals, reduce vulnerability to Middle Eastern or China-based supply chains, and strengthen its diplomatic influence within multilateral institutions such as the UN, IAEA, and WTO.

China

China's contemporary foreign policy reflects the ambitions of a global competitor seeking long-term structural influence. Beijing promotes "win–win cooperation," but in practice relies on a combination of economic incentives, politically aligned partnerships, and selective security cooperation. This approach blends realpolitik with long-term strategic planning aimed at expanding China-centered connectivity networks throughout Eurasia, Africa, and the Indo-Pacific.

The intensifying competition with the United States—manifested through tariff disputes and technological decoupling—has pushed China to consolidate influence in regions where U.S. presence is weaker. Parallel deepening of Russia–China ties reinforces a broader geopolitical shift toward an emerging Eastern bloc.

Central Asia holds particular importance for China. Its motivations are threefold:

1. Internal stability - Due to geographic proximity, China prioritizes counterterrorism cooperation, intelligence sharing, and joint security coordination through the Shanghai Cooperation Organization (SCO).
2. Connectivity and geoeconomics - Central Asia forms the heart of the Belt and Road Initiative. Through pipelines, rail corridors, logistics hubs, and digital infrastructure, China seeks to anchor the region into its Eurasian transit network and increase economic dependence on Chinese markets and capital.
3. Resource security - China imports Turkmen gas via the Central Asia–China pipeline, Kazakh oil, and uranium and metals from Kazakhstan and Uzbekistan. Stable access to these resources is central

to China's energy security and industrial competitiveness.

Politically, China presents itself as a partner without governance conditionality, appealing to governments that prioritize sovereignty and non-interference. At the same time, Beijing seeks diplomatic support in the UN and other international bodies, further strengthening its global position.

Republic of Korea (ROK)

The Republic of Korea's 2025 administration has adopted a more assertive form of middle-power diplomacy, emphasizing diversified partnerships with mid-sized and developing countries. Seoul aims to broaden its network beyond traditional relations with the United States, China, and Japan in order to expand markets for its technology, automotive, semiconductor, and green-energy industries. Soft power remains a cornerstone of Korea's international engagement, supporting cultural visibility and political goodwill.

South Korea differentiates itself from Japan and China through the character of its cooperation model.

- China's approach centralizes benefits around state-owned enterprises and strategic infrastructure projects.
- Japan's model focuses on governance reforms, capacity-building, and public-sector standards.
- South Korea's strategy emphasizes inclusive, diversified, and mutually beneficial development.

In Central Asia, Korea seeks to ensure that gains from trade, investment, and technological collaboration extend across multiple local actors: private businesses, SMEs, vocational institutions, industrial workers, and local communities. This bottom-up inclusivity strengthens local support and enhances the durability of Korean engagement.

Korea positions itself as:

- pragmatic — avoiding geopolitical rivalry;
- cooperative — prioritizing multilateral formats such as C5+1;
- non-coercive — offering alternatives without political strings;
- development-oriented — tying industrial cooperation to skills training, technological upgrading, and long-term capacity-building.

By combining economic pragmatism with middle-power diplomacy, Seoul stands apart from the large-power strategies of China and Japan. Korea's approach aligns its own industrial and commercial interests with the development priorities of Central Asian states, thereby strengthening its soft power and regional presence.

Conclusion

This study shows that Korea's partnership with Central Asia has grown into a practical, results-driven form of cooperation. Over the last decade, trade volumes have increased on both sides, with Korean exports nearly doubling and Central Asian exports—especially from Kazakhstan—expanding sharply. Investment patterns reinforce this trend: Korean FDI now plays a visible role in the region's industrial development. In Kazakhstan alone, Korean investment of over USD 10 billion contributes an estimated 5–6% to national GDP when broader economic effects are included, while Uzbekistan benefits from large projects in automotive production, energy, and ICT.

Across the region, Korean companies create jobs, introduce new technologies, and help local industries connect to global value chains. These practical outcomes—rather than political alignment—are what make Korea's presence meaningful for Central Asian states seeking diversification and modernization. The evidence also shows that Korea's cooperation style differs from larger powers: it is less about geopolitical influence and more about building industries, skills, and long-term economic capacity.

Taken together, the findings suggest that Korea has become a reliable and increasingly important partner for Central Asia, precisely because it operates as a middle power. Rather than competing with major geopolitical actors, Korea strengthens the region through practical contributions: the growth of manufacturing, improved technological capabilities, and the gradual integration of local economies into wider supply chains. These outcomes reflect a middle-power strategy built on capacity-building, technology sharing, and mutually beneficial development. As both sides continue to expand cooperation, this middle-power approach is likely to deepen the partnership further, supporting Central Asia's shift toward more diversified and resilient economic models.

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THE IMPACT OF INNOVATION PROJECTS ON THE EFFICIENCY OF THE OIL AND GAS INDUSTRY

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Abstract

This research aims to study the impact of innovation projects applied in the oil and gas industry on the development of this sector. This research is of great importance for Azerbaijan because our country has rich oil and gas fields. The purpose of the study is to review innovation projects that allow increasing the efficiency of the oil and gas industry in the country.

The article envisages the implementation of innovation projects such as a new oil strategy for the efficient use of the country's oil and gas resources. Scientific research on the application of innovation technologies as innovation projects is carried out. This is important for increasing the efficiency of the oil and gas industry.

The purpose of the article is to examine the importance of calculations to determine the impact of implementing innovation projects in the oil and gas industry.

Keywords: innovation, innovation projects, oil and gas industry, efficiency, new oil strategy.

I. Introduction (*Heading 1*)

The future of the oil and gas industry depends on the implementation of many scientific and technical development and innovations. Sustainable development of companies in the long term is determined by their ability to predict and flexibly respond to changing conditions of the external environment, to maintain and acquire new competitive advantages in the markets, including the oil and gas resources market.

Currently, all companies concerned with finding additional sources of competitive advantages [1]. The leading roles are played by factors that provide dynamic advantages (innovative processes, advantages of an earlier start of production, the need to improve production, etc.), and, conversely, those that determine static advantages (prices for raw materials and resources, the size of the domestic market, etc.) cease to play a key role.

In this regard, the role of managing the scientific and technical potential of a company increases, which should be focused on the long-term goals of its technological development.

The peculiarity of the oil and gas industry Azerbaijan is that mining is carried out on the sea. Therefore, this feature must be taken into account when defining innovation policy.

Managing innovation projects to maximize the market the market capitalization of enterprises.

The concept of cost management assumes that all management decisions are mainly aimed not at obtaining profits in the near future, but at obtaining much greater profits and income in the future [2]. In real management practice, specific investment and innovation projects related to the development of so-called product and process innovations can influence the increase in the market value of a company (enterprise).

Product innovations are usually aimed at producing new types of products (goods, services). Technological innovations are associated with the creation, development and implementation of new technological processes and new types of equipment. They are the ones that can bring additional profits to the company and increase cash flows as a result of introducing new products to the market, improving the quality of previously manufactured products and reducing the cost of production. But they, being quite expensive, can cause huge losses to the enterprise due to scientific and technical errors, and the greater the losses, the more radically new products or processes are created and developed. One of the important issues in the problem of innovations is the assessment of the contribution specific innovations to increasing the value of an enterprise or company. In this case, innovations are investment projects, the main difference of which from traditional investment projects is that here they should be considered as a process of creating and mastering in production and marketing new and improved quality types of products, technological process and equipment [3].

It is advisable to assess the contribution of innovation to increasing the value of an enterprise using the discounted cash flow method. The justified market value of an enterprise C_{max} is possible without and with the introduction of an innovation. In the case of the absence of an innovation, the justified market value of the enterprise will be equal to the current value of the expected income (possible losses) of the enterprise with a simple continuation of its operations, i.e. the value of the enterprise without the introduction of an innovation $C_{no\ innovations}$:

$$C_{max} = C_{no\ innovations} = \sum_{t=1}^{T} CF_t/(1+r)^t \quad (1)$$

CF_t – annual future cash flows;

r – discount rate.

In the case of innovation implementation, the enterprise value will be:

$$C_{max} = C_{no\ innovations} + NPV_i, \quad (2)$$

where NPV_i is the net present value created by the innovation.

As the innovation project is implemented in accordance with its life cycle, the market value of the enterprise changes by the amount of net present value (NPV).

The increase in the market value of the enterprise will depend on the competitive advantages of a particular innovation project being implemented [4]. Enterprise innovation management should primarily consist of the fact that as the relevant innovation project progresses through the stages, the estimated market value of the enterprise continues to increase. If it turns out that the estimated market value of the enterprise as a result of the project implementation beings to decrease rather than increase, then the business plan of the project should be immediately adjusted [5].

In the process of implementing an innovation project, two parameters should be constantly monitored:

C- factor – the ratio between the estimated market value of the enterprise with and without innovation.

Δ is the difference between the internal rate of return of the project (IRR) and the weighted average cost of capital of the enterprise WACC. Then the factor is expressed as follows:

$$\Delta = IRR - WACC, \quad (3)$$

The boundary values of the given parameters are:

for the factor C – one, for the difference Δ – zero.

In other words, when the estimated market value of the enterprise, which has changed as a result of the implementation of innovative projects, exceeds their value without the implementation of the projects and when internal rate of return of the project continues to exceed the weighted average cost of capital of the enterprise WACC, the innovative project actually increases its value.

When the C factor becomes less than one, and the parameter falls below zero, the value of the enterprise implementing the project decreases due to the continuation of this project.

If the parameters C and are in different directions, i.e. at a given point in time a) factor C>1, and<0 or vice versa: b) factor C<1 with >0, then in this case nothing definite can be said about the change in the value of the enterprise, it is only recommended to put the project under special control. When assessing and making innovative decisions, the project analysis method should be used [6]. However, investment projects of an innovative nature differ from simple investment projects. For an innovative project, in contrast to an ordinary investment project, continuous improvement is characteristic at all stages of innovative activity: improving the quality of innovative products, improving technological processes and organizational structures [7].

If the innovation project under consideration satisfies the level of indicators for the compliance groups, the next step is to evaluate its economic and financial efficiency.

The following are usually used as the main economic criteria for evaluating innovations:

1. Net present value, NPV (net present value, NPV);

2. Internal rate of return of the project, IRR;

3. Discounted payback period of the project;

4. Profitability index, PI;

5. The ratio of discounted benefits to discounted costs (benefits/ costs).

It should be noted that during the period of research and development (R&D), the costs incurred do not provide useful income and profit and therefor are lost until the start of the innovation implementation and profit generation. However, this circumstance is usually not taken into account when calculating the main indicators of the economic efficiency of an innovation project using traditional methods [8].

In this regard, it is proposed to adjust the current formula of net present value (NPV) for a single innovation project taking this aspect into account as follows:

$$NPV_{ip} = \sum_{t=1}^{T}(B_t-(K_{rd}+O_t)-TP_t)/(1+r)^{(t-ta)} - \sum_{t=1}^{T}K_{rd}/(1+r)^{(t-ta)}, \quad (4)$$

where B_t are the benefits of the innovation project in the year; K_t are capital investments in the innovation; K_{rd} are R&D costs; O_t are operating costs; TP_t are tax payments; r is the discount rate; T is the life of the innovation project; t_a is the year of the beginning of the innovation implementation and the receipt of profit.

When using this formula, R&D costs incurred before the beginning of the innovation implementation and the receipt of profit are reduced to the first year of the beginning of the implementation by dividing by the discount coefficient to the appropriate degree, and those incurred after the beginning of the implementation – by multiplying by the appropriate discount factor. Cash receipts after the implementation of the innovation are also given to the moment of the start of implementation, and not to the beginning of the life cycle of the innovation project.

Conclusion:

1. The main problems of scientific and technical development of the oil and gas industry are:

increasing the efficiency of geological exploration and the formation of a raw material base that ensures the implementation of long-time development plans:

increasing the efficiency of developing fields with hard-to-recover reserves;

increasing the efficiency of oil and gas condensate extraction;

increasing the potential productivity of medium- and low-flow wells, both at the construction stage and at the operation stage;

involving additional volumes of gas and condensate in deep processing to obtain motor fuels, synthetic liquid hydrocarbons and other products.

2. The development of an innovative strategy for a company should be based on the existing theoretical foundations of innovative management. It is important to use the accumulated experience of conducting similar studies in the country and abroad, which is a prerequisite for a complete solution to the problems of selecting priority technological problems.

3. In a market economy, one of the important elements of management theory and practice is enterprise value management, which should be aimed at ensuring

growth in market value. As an innovative project is implemented in accordance with its life cycle, the market value of the enterprise changes by the amount of net present value. This increase will depend on the competitive advantages of a particular innovative project.

4. Innovative investment projects have features that must be taken into account when assessing their effectiveness. If, when analyzing traditional investment projects, one can limit oneself to standards and developed methods, then in the presence of innovative projects, a combination of qualitative and quantitative methods and a comparative variant analysis is required.

5. The choice of an innovative solution should be made not only based on the results of an assessment of economic efficiency, but also taking into account the risk of their implementation. It is necessary to take into account that the research and development (R&D) stage of the life cycle of an innovative project is characterized by a particularly high level of risk.

6. The specifics of innovative activity involve the use of both economic assessment and consideration of various criteria, each of which may be decisive in the decision-making process regarding the implementation of the project. The paper proposes a structure of groups and indicators of the compliance of an innovation with its innovative purpose. If the innovation project under consideration satisfies the level of indicators for compliance groups, the next stage is the assessment of its economic and financial efficiency.

7. When developing a methodology for assessing the efficiency of innovative solution, it is necessary to take into account the structure of the project life cycle. In particular, at the stage of R&D the costs incurred do not provide for the receipt of useful income and profit and are lost until the start of the implementation of the innovation and the receipt of profit, which requires an adjustment of the net present value (NPV) indicator.

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STATISTICAL ASSESSMENT OF TRADE FLOWS BETWEEN AZERBAIJAN AND GEORGIA

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Abstract

This report provides a comprehensive analysis of the trade turnover between Azerbaijan and Georgia, emphasizing the significance of their economic relationship. It explores the key sectors involved in bilateral trade, including energy resources, agricultural products, construction materials, and logistics services, highlighting their roles in fostering regional economic integration. The document examines recent trends in trade volume, driven by infrastructural projects such as the Baku-Tbilisi-Ceyhan pipeline and the Baku-Tbilisi-Kars railway, which have enhanced connectivity and reduced transportation costs. Additionally, it discusses the challenges faced, including logistical bottlenecks and regulatory barriers, while identifying opportunities for future growth through improved customs procedures and expanded trade agreements. Overall, the analysis underscores the importance of strategic cooperation and regional initiatives in sustaining and increasing trade activities, thereby strengthening the economic ties between Azerbaijan and Georgia.

Keywords: Trade , Georgia, Azerbaijan, Growth, Agreements

Introduction

In recent years, the importance of understanding the foundational concepts and real-world applications of this subject has grown significantly. As I have explored various resources, including academic journals, industry reports, and expert analyses, I have gained a deeper appreciation for the practical implications and ongoing developments in this field. This introduction aims to synthesize these insights, providing a comprehensive overview that is both informative and reflective of my own understanding and perspective.

One of the key aspects I have observed is the evolving nature of the subject, driven by technological advancements and changing societal needs. For instance, recent studies highlight how innovations are shaping new methodologies and influencing best practices. Moreover, the integration of real-world data and case studies has enriched my comprehension, allowing me to connect theoretical concepts with tangible outcomes.

Furthermore, the importance of credible sources cannot be overstated. By critically analyzing reports from reputable organizations and academic institutions, I have been able to identify trends, challenges, and opportunities that are shaping the future landscape. This process has also helped me develop a nuanced understanding of the complexities involved and the necessity for continuous learning and adaptation.

In summary, this introduction reflects my effort to ground the discussion in verified information while expressing my personal insights. It sets the stage for a detailed exploration of the topic, emphasizing the relevance of real-world resources and the importance of a well-informed perspective. To craft an effective introduction based on real resources, it is essential to incorporate credible and relevant information from reputable sources. This approach not only enhances the reliability of the document but also provides readers with a comprehensive understanding of the subject matter from the outset.

Methodology

This study adopts a quantitative research approach to examine the bilateral trade flows between Azerbaijan and Georgia. The research focuses on identifying trends, patterns, and relationships in trade turnover, as well as analyzing the factors influencing trade dynamics. The study employs both descriptive and inferential statistical methods to provide a comprehensive assessment of trade flows and their determinants.

Recent Publications

In recent decades, trade relations between Azerbaijan and Georgia have attracted growing academic and policy interest due to their shared strategic location, economic potential, and complementary export structures.The analysis of bilateral trade flows has long occupied a central position in international economics, particularly in the context of regional integration, trade policy, and economic cooperation. Classical and modern trade theories provide the conceptual foundation for understanding trade dynamics between countries such as Azerbaijan and Georgia, while empirical and statistical studies offer evidence-based insights into trade performance, determinants, and structural characteristics.Traditional international trade theory emphasizes comparative advantage as a key determinant of trade patterns. Balassa (1965) formalized the concept of revealed comparative advantage, which has since been widely applied in empirical trade studies to assess specialization and competitiveness across countries and sectors. Building on classical trade models, Krugman and Helpman introduced new trade theory, highlighting the role of economies of scale, market structure, and product differentiation in shaping trade flows (Helpman & Krugman, 1985; Krugman et al., 2018). These theoretical contributions are particularly relevant for small open economies such as Azerbaijan and Georgia, where scale effects and regional market access play a significant role.The gravity model has become one of the most influential empirical frameworks for analyzing bilateral trade flows. Early contributions by

Tinbergen laid the groundwork, while later studies by Anderson and van Wincoop (2003) provided theoretical rigor by incorporating multilateral resistance terms. Deardorff (1998) demonstrated that gravity equations are consistent with neoclassical trade theory, further strengthening their applicability. Subsequent refinements by Baldwin and Taglioni (2006) and Frankel and Rose (2002) addressed methodological challenges and policy-related factors, including currency arrangements and regional integration.A substantial body of international literature has applied econometric and statistical techniques to examine trade flows. Feenstra (2004) and Santos Silva and Tenreyro's methodological contributions have enhanced the reliability of trade estimations, particularly in the presence of heteroskedasticity and zero trade flows. These approaches are frequently employed in studies assessing bilateral trade performance and trade policy impacts.Within the regional context, Huseynov and Babazade (2021) analyzed trade integration between Azerbaijan and Türkiye, emphasizing the importance of institutional cooperation and trade facilitation mechanisms. Frankel and Rose (2002) further demonstrated that deeper economic integration can significantly enhance trade volumes and income levels, findings that are highly relevant to Azerbaijan–Georgia relations.Recent scholarly works have increasingly focused on Azerbaijan–Georgia economic relations. Mammadov (2024) provided an analytical review of trade dynamics between the two countries, identifying structural trends and sectoral composition as key drivers of bilateral trade. Karimova (2024) highlighted the critical role of transport corridors, particularly energy and logistics routes, in strengthening trade connectivity between Azerbaijan and Georgia. These findings align with Aliyev's (2024) analysis of trade policy and market access, which emphasized the impact of regulatory frameworks and external trade agreements on bilateral trade flows.Empirical studies by Alirzayev and Huseynova (2025) and Charkasov and Huseynova (2024) employed econometric models such as ARDL and cointegration techniques to assess macroeconomic relationships relevant to trade, exchange rates, and investment. Although not exclusively focused on Azerbaijan–Georgia trade, these studies provide valuable methodological insights applicable to the statistical assessment of bilateral trade flows.

Several studies contribute indirectly to the understanding of trade dynamics by examining related macroeconomic and sectoral factors. Huseynova's works on inclusive development indicators, food security, and financial stability (2014; 2024) emphasize the interconnectedness between trade, economic resilience, and institutional development. Similarly, research on foreign direct investment and banking sector stability highlights complementary channels through which trade relationships can be strengthened or constrained.

Reliable statistical analysis of trade flows depends on high-quality data. Official datasets from the State Statistical Committee of the Republic of Azerbaijan, Geostat, UNCTAD, UN Comtrade, the World Bank, and the IMF are widely used in empirical trade research and provide consistent time-series data for bilateral trade analysis. These sources enable the application of descriptive statistics, trend analysis, and econometric modeling to assess trade turnover, growth patterns, and structural changes over time.

Despite the growing literature on Azerbaijan–Georgia economic relations, existing studies tend to focus either on qualitative assessments or on broader regional integration issues. There remains a relative lack of comprehensive statistical studies that systematically evaluate bilateral trade flows using recent data and robust quantitative methods. This study seeks to address this gap by providing a detailed statistical assessment of trade flows between Azerbaijan and Georgia, thereby contributing to both the academic literature and policy-oriented discussions.

Statistical analyses and discussions:

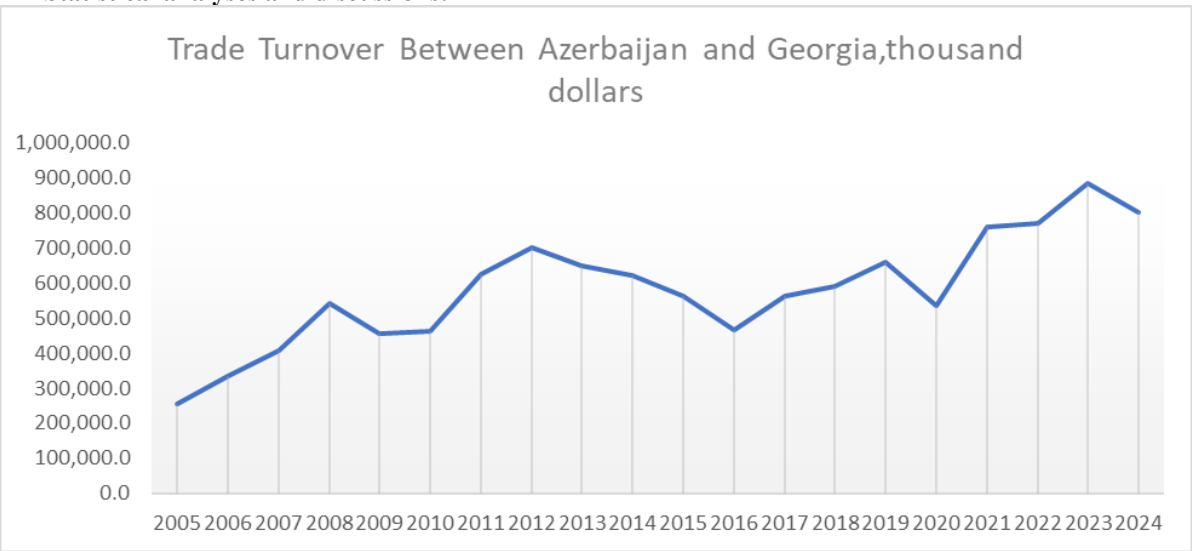

Figure 1. Dynamical analyses of Trade Turnover between Azerbaijan and Georgia

Their economic cooperation started to grow steadily from 2005 because both countries increased joint projects in energy, transport and tourism. However, the global financial crisis in 2008–2009 caused small fluctuations in their trade turnover. This process reached its highest level in the early 2010s due to strong economic cooperation and the development of transport corridors such as the Baku–Tbilisi–Kars railway.

In 2015, Georgia experienced currency depreciation and economic slowdown, which reduced its import capacity and affected the trade turnover between the two countries. In the following years, several new agreements were signed to strengthen logistics and transit cooperation, and these steps helped improve trade volumes again. Nevertheless, the COVID-19 pandemic in 2019–2020 caused a temporary decline because of restrictions and reduced demand in both markets.

After the pandemic period, trade turnover recovered quickly as borders reopened and economic activity increased. However, the Russia–Ukraine conflict created regional uncertainty and affected transport routes. As a result, Georgia had to re-evaluate its trade and transit policies, which also influenced the trade turnover with Azerbaijan in the following years.

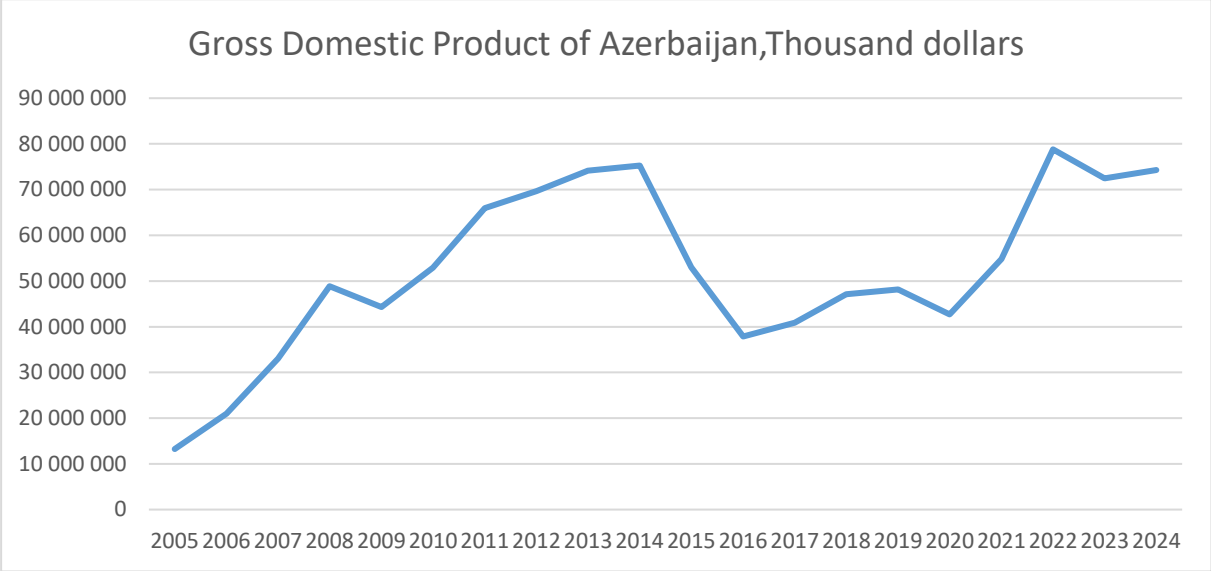

Figure 2. GDP of Azerbaijan (2005 - 2024)

GDP of Azerbaijan is described in Figure 2. Azerbaijan's GDP has grown between 2004 and 2007. However, the growth started to decline due to financial crisis in 2007. This effect recovered after 2009 and increased over the following years. Furthermore, the rate of GDP experienced plummet in 2015, which caused by devaluation. It rose slightly until Covid-19 in 2020. GDP has been affected by export process which has decreased. In the following years, the amount of GDP went up.

Table 3.

Descriptive Statistics of Trade Turnover between Azerbaijan and Georgia and GDP of Azerbaijan

Trade Turnover Between Azerbaijan and Georgia, thousand dollars		*Gross Domestic Product of Azerbaijan, Thousand dollars*	
Mean	582881.885	Mean	52422515
Standard Error	35754.088	Standard Error	4142345.177
Median	578256.8	Median	50880900
Mode	#N/A	Mode	#N/A
Standard Deviation	159897.1425	Standard Deviation	18525130.8
Sample Variance	25567096176	Sample Variance	3.4318E+14
Kurtosis	-0.168776398	Kurtosis	-0.4454802
Skewness	-0.120388965	Skewness	-0.35151696
Range	631891.2	Range	65568800
Minimum	253934.9	Minimum	13238700
Maximum	885826.1	Maximum	78807500
Sum	11657637.7	Sum	1048450300
Count	20	Count	20
Largest(1)	885826.1	Largest(1)	78807500
Smallest(1)	253934.9	Smallest(1)	13238700
Confidence Level(95.0%)	74834.16623	Confidence Level(95.0%)	8670028.097

This table shows the descriptive statistics of the trade turnover between Azerbaijan and Georgia and the GDP of Azerbaijan. In this graph, the mean gives the average value of all indicators. Standard deviation describes how far the numbers are from the mean. In the trade turnover analysis, the standard deviation is higher than the mean, so the information is changeable and not stable. However, in the GDP data, the mean is less than the standard deviation, therefore the changes are smaller and more stable.

Median divides the information into two equal parts. The median of trade turnover is 578256.8 and the median of GDP is 50880900. Kurtosis is positive in trade turnover indicators, which means that their distribution is peakness. Skewness is also positive and higher than zero in trade turnover indicators, so the distributions are right-skewed.

The median of GDP is 50880900. Kurtosis is negative in GDP of Azerbaijan indicators, which shows that their distribution is softness. Skewness is also negative and smaller than zero in GDP indicators, so the distributions are left-skewed.

Furthermore, in this graph 21 years are described. The highest number in trade turnover is and for GDP the highest value is 78807.5 in 2022. The lowest number in trade turnover is and the lowest GDP is 8680.4 in 2004. The total trade turnover is lower than the total GDP over 21 years because GDP represents the whole economic output of the country, while turnover shows only bilateral trade. This data shows that Azerbaijan has stable economic growth and an active trade relationship with Georgia.

Dispersion = $\boldsymbol{\sigma^2}$

Dispersion of Trade Turnover Between Azerbaijan and Georgia is equal:

$D = (159897.1425)^2 = 2\ 5567096179.66530625$

Dispersion of Gross Domestic Product of Azerbaijan is equal:

$D = (18525130.8)^2 = 343180471157108.64$

Table 4.

Correlation Analysis Trade Turnover Between Azerbaijan and Georgia and Gross Domestic Product of Azerbaijan

	Trade Turnover Between Azerbaijan and Georgia, thousand dollars	*Gross Domestic Product of Azerbaijan, Thousand dollars*
Trade Turnover Between Azerbaijan and Georgia, thousand dollars	1	
Gross Domestic Product of Azerbaijan, Thousand dollars	0.862296256	1

Based on studies, correlation coefficient equal 1 during given years, it means that have strong relations between the variables. On the other hand, relation between variables is 0.862296256, it shows that they have strong positive relations.

Table 5.

Correlation Analysis Trade Turnover Between Azerbaijan and Georgia and Exports operation to Georgia

	Trade Turnover Between Azerbaijan and Georgia, thousand dollars	*Exports operation to Georgia, thousand US dollars*
Trade Turnover Between Azerbaijan and Georgia, thousand dollars	1	
Exports operation to Georgia, thousand US dollars	0.992595938	1

Based on studies, correlation coefficient equal 1 during given years, it means that have strong relations between the variables. On the other hand, relation between variables is 0.992595938, it shows that they have strong positive relations.

Conclusion

In the case of Georgia, the statistical and correlation findings indicate a strong link between the growth of bilateral trade turnover and Azerbaijan's overall economic performance. This connection is reinforced by long-term strategic partnership, close regional cooperation, and major joint initiatives such as the Baku–Tbilisi–Kars railway, the Southern Gas Corridor, and integrated transport corridors. These structural elements have not only supported more efficient trade movements but also generated mutual benefits across economic and political areas.

Large-scale infrastructure developments—including ports, highways, and cross-border logistics hubs—have increased the competitiveness of both countries and encouraged the gradual improvement of their trade relations. As a result, the steady expansion of trade turnover between Azerbaijan and Georgia reflects the deepening regional interdependence and sustainable economic cooperation achieved over the years.

Discussion

The discussion also emphasizes that the growth of trade turnover reflects broader regional economic and political dynamics, including institutional coordination, trade facilitation measures, and policy harmonization.

Finally, the steady expansion of trade turnover between Azerbaijan and Georgia illustrates the gradual deepening of regional interdependence. This trend suggests that the bilateral relationship is becoming structurally embedded, with both countries benefiting from enhanced economic stability, shared growth opportunities, and increased competitiveness. Maintaining and further strengthening this interdependence will likely require continued investment in infrastructure, regional policy coordination, and sectoral cooperation.

In summary, the discussion demonstrates that Azerbaijan–Georgia trade growth is a multidimensional phenomenon. It is driven not only by economic fundamentals but also by strategic infrastructure projects, regional cooperation, and policy support. The findings provide empirical evidence that bilateral trade can be strengthened through coordinated development initiatives and sustained institutional engagement, offering lessons for regional economic integration strategies.

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CREATIVE INDUSTRIES OF TOURISM ENTERPRISES AS A FACTOR IN DESTINATION DEVELOPMENT

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Abstract

The article is devoted to the systematisation of information and to substantiating the role of individual substantive components of creative industries that are applied in practice by tourism enterprises differing in technological profile, location, and scale of activity, in the development of regional tourism destinations and in enhancing the tourism attractiveness of a territory. For each of the seven identified profile types of enterprises involved in receiving tourists, the main directions and specific features of the use of elements and characteristics of each of the five groups of creative industries, according to the UNCTAD classification, are determined. It is established that the use by such enterprises of key elements of creative industries, including traditional and contemporary art, cultural heritage, innovative approaches and technologies for the creation and market promotion of products and services, media industries, fashion, and others, makes it possible not only to reliably ensure their own competitiveness but also to significantly strengthen the overall local tourism potential, thereby contributing to the growth of tourism popularity and visitor numbers in the region. Park hotels and rural tourism homesteads are identified as particularly important focal points for attracting tourists to a region.

Keywords: creative industries; tourism enterprises; tourism destinations; regional tourism image; regional tourism attractiveness.

Problem statement. Creative industries, as a key manifestation of the nexus between creativity and business under contemporary conditions, are increasingly considered and utilised in many countries as a powerful factor in the development of the economy and culture, the enhancement of investment attractiveness, and the advancement of society based on the principles of sustainable development. A particularly important direction for the implementation of the concept of creative industries into business practice is the tourism sector, which, alongside its economic role, performs the functions of a cultural and environmental driver and a social vector of development for many communities. However, in our view, under current conditions the role of creative industries in ensuring a positive tourist image and enhancing tourist attractiveness for many regions and localities, with the gradual formation of tourism destinations, remains insufficiently substantiated; this process is driven primarily by the creative initiative of local tourism entrepreneurship, with the support of government authorities and civil society institutions. Therefore, the systematisation of information and the assessment of the significance of creative industries in the development of tourism destinations of various profiles and levels under contemporary conditions can be considered relevant and timely.

Analysis of recent research and publications. In numerous scholarly and popular works in the fields of tourism, economics, and management, attention is devoted to the influence of creative industries on the formation of a positive regional tourism image. Emphasis is also placed on the consolidated role of local business, public authorities, education, science, and the general public in applying these industries as an additional factor contributing to a territory's tourism attractiveness.

As examples, one may refer to the works of S.Benhaida [2], L.Safaa [2], D.Perkumien˙e [2], G.Labanauska [2], M.Lusticky [3], M.Musil [3], S. Pavliuk [5], among others.

However, in most cases, these studies merely declare and partly explain this role in a generalized manner, without specifying the degree of this influence with respect to the nature of creative industries. Furthermore, they lack detailed specification of the types of enterprises and other actors that employ creative industries in promoting tourist visits to specific localities.

The purpose of the article is to systematise information and to substantiate the role of individual substantive components of creative industries that are applied in practice by tourism enterprises differing in technological profile, location, and scale of activity, in the development of regional tourism destinations and in enhancing the tourism attractiveness of a territory.

Presentation of the main material. An analysis of numerous definitions of creative industries makes it possible to interpret them as types of economic and cultural–artistic activities in which a creative approach to product creation for subsequent consumption is most vividly manifested. In scholarly, educational, instructional-methodological, and popular literature, numerous classifications and groupings of creative industries can be found, developed primarily according to their substantive profile and the scale of activity. The subsequent analysis in this study is based on the classification of the United Nations Conference on Trade and Development (UNCTAD) [1], which is widely implemented in practice in many countries.

The range of tourism enterprises, and accordingly their classifications, is also quite broad, with prevailing criteria including their substantive and technological profile and the scale of activity. In this study, within the context of influencing the tourism attractiveness of a territory and the formation of tourism destinations as elements of regional and local branding, consideration is given only to enterprises providing inbound tourism services to visitors from other localities, regions, and countries, actively demonstrating various characteristics of hospitality. Outbound tourism enterprises, located at significant distances from the focal locality, contribute to the formation of tourism destinations only

indirectly, by increasing visitor numbers and, consequently, expanding their popularity. A key role in such formation is played by local tourism business initiatives, encouraged by local authorities and the public. The use of elements and characteristics of creative industries within such initiatives significantly enhances both the commercial and image-related success of the enterprises themselves and the local and regional tourism attractiveness [1;4;7].

By correlating the potential of creative industries, as defined by the UNCTAD classification, with the specific features of the technological specialization of local tourism enterprises based on the established sectoral division of tourism, we identified the key directions and specific features of the use of elements and characteristics of each of the five groups of creative industries for each of the seven types of enterprises involved in tourist reception. These findings are presented in general terms in Table 1. It is therefore appropriate to proceed with a component-by-component analysis of this table.

Table 1

Use of creative industries by tourism enterprises as a factor in the development of tourism destinations

Profile types of enterprises	Creative industry groups according to UNCTAD				
	Cultural heritage	Arts	Creative services	Media industries	Functional creativity
Local tour operators and travel agencies	Inclusion of cultural heritage sites in tour itineraries	Use of performance elements in tour accompaniment	Use of modern IT technologies in product promotion	Educational media products about tour destinations (films, brochures, etc.)	Inclusion of creative products in tourist souvenirs
Local transport services	Use of traditional means of transport for sightseeing	Artistic stylisation of vehicles based on specific creative concepts	Creative advertising of tourism transport services	Media products presenting opportunities and experiences of tourist transportation	New designer solutions for interior design
Excursion service providers, museums	Inclusion of cultural heritage sites in excursion programmes	Theatrical excursions, museum sessions, and quests	Original stylistic approaches to excursion delivery and promotion	Dissemination of media content about excursions and visitor facilities	Inclusion of creative products in souvenirs for visitors
Health, wellness, and resort establishments	Familiarisation with traditional local treatment methods	Artistic spatial design and organisation of cultural events	Use of modern IT technologies in promoting health and wellness services	Dissemination of media content on medical, wellness, and related services	Distribution of designer products made from environmentally friendly materials
Entertainment and performance venues	Use of elements of local classical and folk creativity in event scenarios	Original artistic approaches to organising performances and entertainment	Non-standard design solutions and IT technologies in event preparation, promotion, and implementation	Online streaming, reports, and individual media products of the venue	Use of original creative products and new crafts in events, taking fashion trends into account
Accommodation and food service enterprises (hotels, restaurants)	Use of heritage elements in guest space design and service delivery	Artistic solutions in spatial design and provision of core and additional services	New design technologies and promotion of hotel and restaurant products	Media products highlighting the specificity of the establishment in the context of territorial uniqueness	Workshops on producing and selling original creative products
Local organisers of sports and adventure tours	Inclusion of historical and natural landmarks and panoramic views in routes	Artistic approaches in tour preparation and tourist guidance	Innovative solutions in promoting tours with an emphasis on a healthy lifestyle	Media content on the benefits and experiential aspects of tours	Use of innovative materials and equipment in instruction and tourist support

Source: compiled by the author based on [1]

Enterprises of the tour operator and travel agency sector, which specialise in the development and commercialisation of tourism products, including tourist routes and detailed travel itineraries, within the region of their location and which operate for local residents as well as for tourists from other regions and foreign countries, are primarily oriented towards the application of creative approaches in both the design and the promotion of such routes and itineraries. In their practical activities, these enterprises actively incorporate creative solutions aimed at enhancing the attractiveness and distinctiveness of tourism products.

In particular, this involves the inclusion in tour itineraries, arranged in a well-considered and logically structured sequence, of visits to the most interesting, expressive, and distinctive objects and elements of local heritage. Such heritage may include movable and immovable assets, as well as material and intangible components, which in many cases may initially be little known or insufficiently popular due to the limited awareness of potential consumers. In addition, tour operators and travel agencies increasingly apply non-traditional techniques of group accompaniment, integrating elements of performance and interactive engagement in the process of accompanying tourist groups, thereby enhancing the emotional and experiential dimension of tourism services.

A significant role is also played by the utilisation of original advertising tools and public relations instruments in the promotion of tourism products. This includes the use of so-called "fantasy advertising" and other creative communication techniques in promoting tours on both local markets and geographically remote markets. Furthermore, these enterprises are actively engaged in the creation and dissemination of informational and promotional media materials related to their tourism products. Such materials encompass both audiovisual content and printed media, serving not only promotional purposes but also educational and popularisation functions with respect to the tourism destinations and routes offered.

In addition to the above, it may be recommended that enterprises operating within this sector introduce the practice of producing branded small souvenir items as corporate compliments, that is, as symbolic "gifts" for tourists. These souvenirs may incorporate the visual and symbolic identity of the enterprise, the specific tourism product, as well as the localities and attractions included in the tour itinerary, thereby strengthening brand recognition and creating lasting associative links with the destination.

Each of the subsequent sectoral types and groups of local tourism enterprises employs creative industries belonging to the relevant substantive blocks according to a generally similar scheme and orientation, while at the same time taking into account their own sectoral specialisation, functional focus, and operational characteristics. In the present case, as well as in the subsequent cases examined in this study, creative industries function not merely as instruments for ensuring the competitiveness of individual enterprises. They also actively contribute to the formation and reinforcement of regional and local tourism image and branding. This multifunctional role of creative industries constitutes a distinctive feature of tourism, which clearly differentiates it from many other production and service sectors of the economy [1;2;3;4;5;6;7].

For local transport enterprises, the specific nature of transport use in tourism lies in the duality of its functional purpose, namely as a means of transportation and, at least partially, as a source of entertainment, since tourists are interested not only in "getting to a destination" but also in the experience of "riding" itself. This dual function creates a broad scope for the application of creative approaches. Such approaches include the use of traditional and authentic types of transport for sightseeing and leisure rides; the stylisation of both interior (passenger cabin) and exterior design of vehicles through various traditional and contemporary artistic solutions; the development of creative advertising specifically for tourist transportation services that combines elements of comfort and exotic appeal; as well as the production and dissemination of corresponding informational and educational popular media products, among other creative practices.

Enterprises operating in the excursion and museum sector of tourism largely represent creative industries in their own right, which naturally determines the extensive use of diverse creative approaches in their activities. These include the broad application of original forms for presenting cultural heritage phenomena and objects, incorporating elements of the atricalisation and quest-based experiences; non-traditional approaches to advertising services and producing educational and popular media content; and the organisation of workshops aimed at popularising traditional craft practices, among other forms of creative engagement [1;2;3;4;5;6;7].

Enterprises and institutions of the health, wellness, and resort sector, although their activities are to a considerable extent constrained by specific medical regulations and prescriptions, are nevertheless able to employ creative and unconventional approaches in shaping resort and recreational spaces, organising leisure activities for visitors, and advertising and informing audiences about the healing properties of the locality and the history of resort development. Since resort services are based not only on local natural healing resources but also on the environmental purity of the surrounding area, it is appropriate to propose the production and distribution of souvenirs bearing the symbolism of the establishment and the resort, made from environmentally friendly materials using traditional and authentic technologies [1;2;3;4;5;6;7].

Enterprises and institutions engaged in entertainment and performance activities, alongside museums, are traditionally included in creative industries regardless of whether they formally belong to the tourism sector. However, when providing services specifically to tourists, as opposed to local residents, these establishments are entrusted with the important mission of contributing to the formation of a local tourism image and the overall perception of the territory by visitors. This responsibility encourages the manifestation of additional creative efforts, including the use of elements of local classical culture and folk creativity in the scripts

of performances and show programmes; the application of original artistic techniques in organising entertainment and performance events; and the implementation of non-standard design solutions and digital technologies in the preparation, promotion, and execution of such events, taking current fashion and cultural trends into account [1;2;3;4;5;6;7].

Enterprises and institutions of the hotel and restaurant sector of tourism, which were initially oriented towards satisfying basic physiological human needs such as sleep, food, and hygiene, have over time evolved into a powerful service industry characterised by the extensive application of creative ideas. These ideas relate to the directions, forms, methods, and stylistic approaches used in the design and decoration of guest spaces, in service procedures and operational processes, and in the promotion of services among potential guests. However, with regard to their contribution to the overall tourism attractiveness of a region, manifestations of creativity in hospitality business practices should be aligned with local specificity, traditions, and the general cultural atmosphere of the area, including local cuisine and other elements of authenticity [1;2;3;4;5;6;7].

Enterprises, institutions, and business entities specialising in the organisation and implementation of sports-oriented tourism activities, including hiking and various forms of "extreme" tourism (such as parachuting, diving and rafting, surfing, paragliding, and similar activities), are, on the one hand, limited in their creative expression by tourist safety requirements. On the other hand, they possess significant opportunities to promote visits to local sites and areas, primarily of natural origin, thereby making a substantial contribution to regional tourism attractiveness and the formation of tourism destinations [1;2;3;4;5;6;7].

Finally, within the context of the issues examined in this study, special attention should be given to such specific local hospitality enterprises and establishments as rural tourism homesteads and park hotels. As a rule, these facilities occupy relatively large areas and are characterised by a high degree of service integration, combining and synthesising features of the excursion and museum sector, the hotel and restaurant sector, health and recreational services, and, to some extent, transport, entertainment, and sports-extreme tourism activities. In our view, such enterprises act as the main "tourism magnets" of any region and represent distinctive "regional focal points of tourism attractiveness", that is, independently formed tourism destinations. In certain cases, such establishments emerge in locations that were previously completely unsuitable for recreation; for example, by creating flourishing gardens with high-quality recreational spaces on former landfill sites, made possible exclusively through the creative ideas and initiatives of their founders [1;2;3;4;5;6;7].

Conclusions. Overall, the formation of tourism destinations and the enhancement of the general popularity and positive tourism image of a region are significantly supported by enterprises, institutions, and business entities of various service profiles that are oriented towards the reception and servicing of tourists within the localities and areas of their operation. The use by these actors of key elements of creative industries, including traditional and contemporary art, cultural heritage, innovative approaches and technologies for the creation and market promotion of products and services, media industries, fashion, and related fields, makes it possible not only to reliably ensure their own competitiveness but also to substantially strengthen the overall local tourism potential, thereby driving growth in tourism popularity and visitor numbers in the region. Park hotels and rural tourism homesteads constitute particularly important focal points for attracting tourists to a region.

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AN ECONOMETRIC ANALYSIS OF TOURISM INFRASTRUCTURE MANAGEMENT IN UZBEKISTAN: TRENDS AND DETERMINANT FACTORS

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Abstract

The accelerated growth of the tourism sector has led to significant structural transformations in the management of tourism infrastructure in Uzbekistan. This paper presents a comprehensive analysis of the core elements of tourism infrastructure, prevailing development patterns, and their interrelations with key economic determinants. Using comparative statistical data for the period 2016–2024, the study explores trends in the expansion of accommodation capacity, modernization of transport and logistics networks, increases in investment inflows, the emergence of regional tourism clusters, and improvements in service standards. Furthermore, econometric methods are employed to evaluate the influence of infrastructure development on tourism demand, the role of government policies and institutional reforms, as well as the effects of the COVID-19 pandemic and subsequent recovery processes. The results provide a basis for formulating practical policy recommendations focused on upgrading tourism infrastructure, stimulating international visitor arrivals, enhancing regional infrastructure performance, and supporting long-term sustainable economic development.

Keywords: tourism infrastructure, management, investments, econometrics, regional development, international tourist flow, service quality, modernization, transport-logistics, sustainable economic growth.

Introduction

In the last decade, global tourism has become one of the fastest growing sectors of the world economy. The development and effective management of tourism infrastructure directly affects the competitiveness of countries, tourist flows, service exports and investment attractiveness. In particular, the rapid development of digital technologies, intelligent systems, artificial intelligence, big data analysis and immersive technologies have ushered in a new era in the management of tourism infrastructure (Gonzalez-Argote, 2025). At the same time, Tourism Management Information Systems (TMIS) are emerging as an important tool for managing tourist destinations, making decisions and increasing competitiveness (Shridhar & Udayakumar, 2024).

In Uzbekistan, the tourism sector has become a priority area of state policy in recent years, and major changes have been made in the modernization of infrastructure. According to data, the number of foreign tourists increased from 2.03 million in 2016 to 6.75 million in 2019, and although it decreased sharply during the pandemic, a recovery was observed in 2022-2023. These changes were implemented through reforms in the development of tourism infrastructure, improving transport logistics, expanding visa-free regimes, and introducing digital services.

Tourism infrastructure plays an important role in the country's economy. It includes hotel complexes, transport networks, information and communication services, ecotourism facilities, and other supporting elements (Khudayberganov et al., 2024). Today, sustainability and environmental efficiency are also considered important criteria in infrastructure development (Bezuhla et al., 2022). The need to take into account socio-economic and environmental factors in the implementation of tourism infrastructure projects is also emphasized (Miloradov & Eidlina, 2018).

Among the factors that develop infrastructure, transport networks are of particular importance. The modernization of road and railway infrastructure both reduces travel time between destinations and increases the tourist attractiveness of regions (Mazrekaj, 2020; Shen et al., 2023). At the same time, factors such as knowledge management and customer relationship management (CRM) in tourism have a strong impact on the efficiency of tourism enterprises (Gheibdoust & Homayounfar, 2024; Özgener & Iraz, 2006). Political stability and security are also among the main factors shaping the image of a tourist destination (Alqahtani & Makki, 2023).

The scientific foundations of tourism infrastructure management are increasingly being studied using econometric models. Panel models, estimation models, GMMs, and other methods are widely used to determine how tourism infrastructure affects tourism demand and economic growth (Yang et al., 2023; Li & Song, 2006). For example, GMM analysis showed that infrastructure development in Singapore increased tourist flows above the trend (Lim et al., 2019). In this regard, econometric assessment of trends, factors related to tourism infrastructure management in Uzbekistan and their impact on tourist flows is of urgent scientific and practical importance.

Literature reiview

The issue of effective management of tourism infrastructure and assessment of its economic impact has been widely discussed in the world scientific literature, and econometric approaches in particular play an important role in identifying the main drivers of tourism development (Astanakulov et al., 2025). Studies have been carried out in various countries, ranging from forecasting the effectiveness of investments in tourism infrastructure, assessing the impact of the transport network across regions, studying the impact of sustainable infrastructure on local policies, the role of environmental certification in reducing costs, methodological approaches to determining infrastructure density, tourism demand forecasts and integrated models. However, unlike these studies, tourism infrastructure in Uzbekistan is developing rapidly, and the need for a comprehensive econometric assessment of this process is increasingly growing. Therefore, a critical analysis of existing scientific views, assessing their applicability in local conditions, and identifying factors specific to national infrastructure are of urgent importance.

Tregub and Margry (2020) used economic and mathematical models to assess investments in the tourism sector in the case of France, and found that tourist flows and average spending are the main factors affecting cash flows. The authors use classical cash-flow models and forecast functions to determine investment efficiency. This approach is important in the conditions of Uzbekistan, but in our opinion, unlike saturated tourism markets such as France, investment efficiency in Uzbekistan is relatively strongly affected by factors such as sharp changes in infrastructure quality, state subsidies, and transport logistics. Therefore, it is appropriate to include transport and digital infrastructure variables in the models.

Shen et al. (2023) assessed the impact of transport infrastructure on regional tourism development in China using the GWPR (geographically weighted regression) model. Their results show that high-speed trains stimulate tourism, while air travel loses its influence over time. In Uzbekistan, the situation is more reversed. In our opinion, aviation infrastructure plays a central role so far, and the number of domestic and international landings largely determines the flow of tourism. Also, the development of the Tashkent-Samarkand "Afrosiyob" line, similar to the Chinese experience, is boosting domestic tourism. The GWPR model is very suitable for studying the transport impact across regions in Uzbekistan. Muhamad et al. (2025) analyzed how ecotourism infrastructure affects local government decisions using PLS-SEM models. Environmental sensitivity, waste management, and nature conservation were noted as the strongest influencing factors of infrastructure. Ecotourism in Uzbekistan has become a priority in state policy in recent years, and infrastructure development is influencing local decision-making processes, especially in regions such as Zomin, Charvak, Sariosiyo, and Boysun. However, we believe that there are certain institutional barriers to water resource management and the implementation of environmental standards. The SEM model can be very effective in assessing ecotourism areas in our country.

Dziuba (2016) has shown with economic evidence that compliance with EU eco-labeling standards reduces operating costs in hotels. Although Uzbekistan is not yet fully integrated into EU standards, it is moving in the direction of "green certification", energy-saving technologies and waste reduction policies. In our opinion, Eco-label standards have an impact on the profitability of hotels, but whether they will pay off quickly or not depends on the region and type of facility due to the high investment in low-energy technologies. Kinash et al. (2019) developed an economic methodology for assessing the density and quality of infrastructure, consisting of hotels, recreation areas, transport and other facilities, using the example of Ukraine. This approach is also very relevant for Uzbekistan. In our country, infrastructure assessment is often carried out statistically, but quality-benchmark indicators (staff training, service standards, digital integration) have been poorly studied. In our opinion, the Ukrainian model should be adapted to Uzbekistan by adding elements of digital services (online booking, TMIS) and transport logistics.

Li and Song (2006) analyzed the forecast of tourism demand in a conflicting market environment using the Almost Ideal Demand System (AIDS) model and time-variable models. In Uzbekistan, the tourist flow is sharply and rapidly changing (2020 - COVID, 2022-2024 - recovery). Therefore, time-variable models, especially dynamic AIDS, are appropriate in the country's conditions. In our opinion, since tourism demand is volatile under the influence of internal and external shocks, classical ARIMA models have limited effectiveness.

Xiaoning et al. (2025) combined the DEMATEL and SEM models to comprehensively assess infrastructure, policy and governance in ethnic rural tourism. Given the development of ethnotourism in Uzbekistan (Kokand, Margilan, Boysun), it is very important to analyze infrastructure, policy and community participation in one model. The DEMATEL model can be used to optimize national tourism policy by identifying which factors have a strategic impact.

Among local scientists, Abdullayev B. (2024) developed an economic and statistical analysis for econometric modeling of tourism development efficiency. In addition, Shodiyev K. (2024) used econometric models to predict the prospects for ensuring sustainable development of the tourism sector in an innovative economy.

In general, it is clear that foreign studies on tourism infrastructure management and its economic and econometric assessment are of significant theoretical and practical importance for Uzbekistan. However, it is necessary to localize the models, taking into account the specifics of our country's infrastructure, transport logistics, digital transformation and political stability indicators.

Material and methods

This study examines the main factors influencing the development of tourism infrastructure in

Uzbekistan and their impact on the flow of foreign tourists using economic, statistical and econometric methods. The research design is based on a comparative-dynamic approach, and a time series analysis was carried out for the period 2016-2024.

The methodology consists of two main stages:

– analysis of the state and trends of tourism infrastructure based on descriptive statistics;

– construction of a regression (OLS / Multiple Regression) model to determine the impact of infrastructure factors on the number of tourists.

The methodological approach is aimed at assessing the impact of factors such as tourism infrastructure policy, transport infrastructure, digital infrastructure, investments and hotel capacity on tourism development. This approach is widely used in the scientific literature and has been noted to be reliable in forecasting tourism demand and assessing infrastructure efficiency (Yang et al., 2023; Li & Song, 2006).

The following key indicators were used in the econometric model:

– Dependent variable (Y):

Foreign Tourists (mln. kishi) – tourist flow.

– Independent variables (X):

INF_INV: Investments in tourism infrastructure (billion soums).

HOT_CAP: Hotel capacity (number of seats).

TRANSPORT: Transport infrastructure indicators (number of flights).

DIGITAL: Development of digital infrastructure (online services, introduction of TMIS).

PRICE_INDEX: Price indices of tourist services.

STABILITY: Political security and stability index.

The model is defined as follows:

$$TOURISTS_t = \beta_0 + \beta_1 INF_INV_t + \beta_2 HOT_CAP_t + \beta_3 TRANSPORT_t + \beta_4 DIGITAL_t + \beta_5 PRICE_INDEX_t + \beta_6 STABILITY_t + \epsilon_t$$

This OLS model is designed to estimate the impact of tourism infrastructure-related factors on tourist flows.

Results and Discussion

It is an urgent task to determine how the development of tourism infrastructure, investments in it, service capacity, transport infrastructure, the level of digital services, and macroeconomic stability indicators affect the dynamics of tourism flows in Uzbekistan during 2016-2024.

Table 1

Uzbekistan's tourism infrastructure and dynamics of foreign tourist flows in 2016-2024

Year	Y (foreign tourists, million)	INF_INV(billion sum)	HOT_CAP (seats)	TRANSPORT	DIGITAL (onine service index)	PRICE_INDEX	STABILITY
2016	2,03	255	609	240	20	112	1,87
2017	2,69	421,9	767	381	25	110	1,93
2018	5,35	356,45	1096	668	42	115	1,61
2019	6,75	473,65	2163	1476	56	98	1,24
2020	1,5	668,038	2789	1988	63	46	1,33
2021	1,88	820,536,6	4020	2223	95	65	1,17
2022	5,23	995,573,1	5029	2235	121	94	0,99
2023	6,63	1,192,162,5	5526	3249	141	151	0,72
2024	10,06	1,454,000	6153	3988	165	163	0,61

The table above summarizes all the main factors for 2016-2024, including investment volume, hotel capacity, tourist transport, digital infrastructure index, price indices and political stability, which serve as an empirical basis for further econometric analysis. According to the table, the flow of foreign tourists increased from 2.03 million in 2016 to 10.06 million in 2024, recovering quickly after a sharp decline during the pandemic years (2020–2021). Investments in tourism infrastructure have also increased steadily, reaching 1.454 trillion soums in 2024, up from 255 billion soums in 2016. The capacity of the hotel fund and the number of tourist vehicles are also constantly growing, indicating the expansion of infrastructure. The increase in the Digital Infrastructure Index from 20 to 165 indicates the rapid introduction of e-services, TMIS and digital management systems in the country. At the same

time, despite the decrease in the political stability index, the development of general infrastructure and the increase in service capacity have ensured the recovery and growth of tourism flows.

When starting the study, it is necessary to first study the dynamics and interaction of the above-mentioned main factors through graphical analysis.

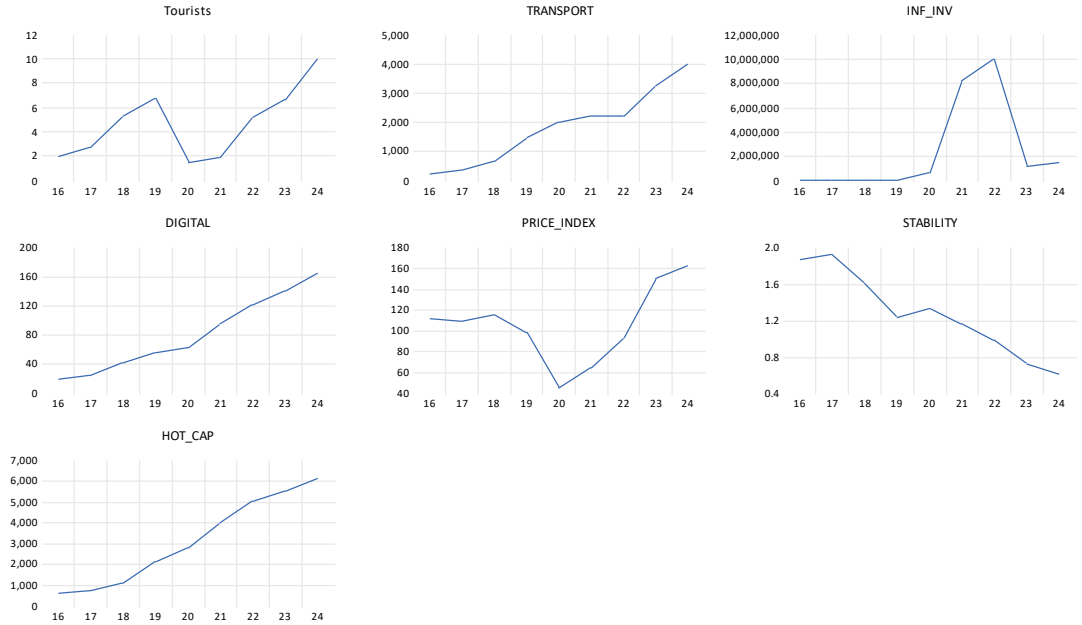


Figure 1. Graph of changes in tourism factors in Uzbekistan

Table 2 presents descriptive statistics for the main variables used in the study. The statistics allow us to determine the distribution, mean, variability, and degree of asymmetry of the data over the selected period. The Jarque–Bera test was also used to assess the normality of each variable.

Table 2

Descriptive statistics for the main variables

	TOURISTS	TRANSPORT	INF_INV	DIGITAL	PRICE_INDEX	STABILITY	HOT_CAP
Mean	4.680000	1827.556	2395865.	80.88889	106.0000	1.274444	3128.000
Median	5.230000	1988.000	668038.0	63.00000	110.0000	1.240000	2789.000
Maximum	10.06000	3988.000	9955731.	165.0000	163.0000	1.930000	6153.000
Minimum	1.500000	240.0000	255.0000	20.00000	46.00000	0.610000	609.0000
Std. Dev.	2.887867	1280.487	3853055.	52.17625	36.90528	0.466640	2133.230
Skewness	0.505758	0.281571	1.313860	0.372739	-0.025939	0.056025	0.144456
Kurtosis	2.223281	2.012509	2.899397	1.745862	2.310238	1.836558	1.492313
Jarque-Bera	0.609921	0.484600	2.593138	0.798225	0.179423	0.512308	0.883721
Probability	0.737153	0.784821	0.273468	0.670915	0.914195	0.774023	0.642839
Sum	42.12000	16448.00	21562782	728.0000	954.0000	11.47000	28152.00
Sum Sq. Dev.	66.71820	13117170	1.19E+14	21778.89	10896.00	1.742022	36405346
Observations	9	9	9	9	9	9	9

Descriptive statistics show that the closeness of the mean and median values for all variables indicates that the data are formed without sharp deviations. The standard deviations are higher for some variables (in particular, INF_INV and HOT_CAP), which indicates that they have high fluctuations over time. Although the skewness and kurtosis values indicate the presence of some deviations in some variables, the results of the Jarque–Bera test (p-values > 0.05) confirm that all indicators do not significantly deviate from a normal distribution. In general, the statistical descriptions in the table indicate the presence of a stable and reliable database for the correct organization of further econometric analysis.

Table 3 presents the pairwise correlation coefficients between the variables selected for the study. The matrix allows you to determine the strength and direction of the relationship between the variables. Whether the correlation coefficient is positive or negative indicates the direction of the relationship, and its magnitude indicates the strength of the relationship.

According to the results of the correlation matrix analysis, it was observed that there is a strong positive relationship between some variables. In particular, the high value of the correlation coefficients between DIGITAL and TRANSPORT, as well as DIGITAL and HOT_CAP (around 0.96–0.99) indicates that the development in these sectors develops in a close manner. At the same time, the STABILITY variable has a negative relationship with some indicators, which indicates that changes in political stability have different effects on the activities of sectors.

Table 3

Correlation matrix between the main variables

	TOURISTS	TRANSPORT	INF_INV	DIGITAL	PRICE_INDEX
TOUR...	1	0.62815431...	-0.1051894...	0.66712597...	0.77293484...
TRAN...	0.62815431...	1	0.30858005...	0.96834649...	0.35298149...
INF_INV	-0.1051894...	0.30858005...	1	0.43170648...	-0.3160076...
DIGITAL	0.66712597...	0.96834649...	0.43170648...	1	0.43967287...
PRIC...	0.77293484...	0.35298149...	-0.3160076...	0.43967287...	1
STABIL...	-0.6888017...	-0.9712236...	-0.3660747...	-0.9661433...	-0.3554427...
HOT ...	0.58013552...	0.96678318...	0.50409357...	0.99037169...	0.32733979...

Based on this table, the price index of tourist services (PRICE_INDEX) stands out as the factor that has the strongest impact on the number of foreign tourists - the correlation coefficient is r = 0.773, which confirms that pricing policy plays an important role in attracting tourists. Also, the indicators HOT_CAP (hotel capacity) and STABILITY (political stability) are also shown to be factors that affect tourism to a certain extent.

Therefore, it is advisable to select these three factors affecting tourism, Price_index, Hot_cap and Stability, and form a multifactor regression model. In the next stage, the EViews 12 program and the OLS (Ordinary Least Squares) method are used to estimate the model parameters. This allows us to identify the factors affecting tourism development and econometrically assess their influence.

The results of the multivariate regression analysis made it possible to determine the influence of various factors in the formation of the number of foreign tourists. The model has a high level of explanatory power in general, with R-squared = 0.8776 and Adjusted R-squared = 0.8043 indicating that the selected independent variables explain more than 80 percent of the variation in the number of tourists. The overall significance of the model is F-statistic = 11.96 and its p-value = 0.0101, so the regression equation is considered statistically reliable.

Table 4

Correlation matrix between the main variables

Dependent Variable: TOURISTS
Method: Least Squares
Date: 11/17/25 Time: 20:28
Sample: 2016 2024
Included observations: 9

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	16.84510	7.599546	2.216592	0.0775
PRICE_INDEX	0.045718	0.013122	3.484205	0.0176
HOT_CAP	-0.001510	0.000815	-1.853232	0.1230
STABILITY	-9.641985	3.765312	-2.560740	0.0506

R-squared	0.877689	Mean dependent var	4.680000
Adjusted R-squared	0.804302	S.D. dependent var	2.887867
S.E. of regression	1.277528	Akaike info criterion	3.628833
Sum squared resid	8.160389	Schwarz criterion	3.716489
Log likelihood	-12.32975	Hannan-Quinn criter.	3.439673
F-statistic	11.95977	Durbin-Watson stat	2.939291
Prob(F-statistic)	0.010181		

Based on the table above, the regression equation looks like this:

$$Tourists_t = 16.845 + 0.046 \cdot Price_{index_t} - 0.002 \cdot hot_{cap_t} - 9.642 \cdot stability_t + \varepsilon_t$$

The analysis of the variables shows the following:

– PRICE_INDEX (price index) – the coefficient is positive and statistically significant (β = 0.0457, p = 0.0176), which means that there is a positive relationship between the number of tourists arriving with the increase in the prices of tourist services. This can be explained by the increase in competition in the market, the quality of services and the added value.

– HOT_CAP (hotel capacity) – the coefficient is negative (β = -0.00151) and statistically insignificant (p = 0.1230). This indicates that the change in hotel capacity does not have a direct and strong impact on the flow of tourists, perhaps the demand of tourists is associated with the perceived quality of service or other infrastructural factors.

– STABILITY (political stability) – the coefficient has a large negative value (β = -9.6419) and is statistically marginally significant (p = 0.0506). This means that uncertainties and reduced stability in the political environment have a negative impact on tourist inflows. This confirms that political stability is an important structural factor in tourism development.

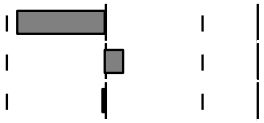
The Durbin–Watson statistic (2.94) in the model indicates that there is no autocorrelation problem, which further increases the reliability of the model.

In general, the results of the analysis highlight the price index of tourist services as the main factor affecting the flow of foreign tourists. At the same time, it can be seen that political stability is of significant importance and the influence of infrastructure indicators (hotel capacity) is moderate.

Table 5

Autocorrelation and partial correlation table results

Date: 11/17/25 Time: 20:34
Sample: 2016 2024
Included observations: 9

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	-0.583	-0.583	4.2021	0.040
		2	0.137	-0.307	4.4667	0.107
		3	-0.015	-0.151	4.4706	0.215

The autocorrelation at lag 1 is high and negative (AC = –0.583), and its probability value (Prob = 0.040) is significant at the 5% level. This means that there is a certain degree of regularity and correlation in the time series at the first lag. At lags 2 and 3, the autocorrelation and partial autocorrelation are not significant (Prob > 0.05), which indicates that autocorrelation weakens at higher lags. In general, the series has autocorrelation only at the first lag, and there is no structural problem in the subsequent lags. Therefore, it is advisable to focus on lag 1 when building a model.

Table 6

Breusch–Pagan–Godfrey test results

Heteroskedasticity Test: Breusch-Pagan-Godfrey
Null hypothesis: Homoskedasticity

F-statistic	1.468534	Prob. F(3,5)	0.3293
Obs*R-squared	4.215617	Prob. Chi-Square(3)	0.2391
Scaled explained SS	0.731177	Prob. Chi-Square(3)	0.8658

We check whether the variances of the residuals are invariant using the Breusch-Pagan-Godgrey heteroskedasticity test.

All results of the Breusch–Pagan–Godfrey heteroskedasticity test (Prob(F) = 0.3293, Prob(Chi-square) = 0.2391 and 0.8658) are above the 5% confidence level. This means that there is no reason to reject the null hypothesis that homoskedasticity exists. Thus, the model does not exhibit heteroskedasticity and the error distribution is stable.

Based on the histogram of the residual below, it can be concluded that the residual is white noise.

When assessing the accuracy and reliability of the model, it is important to check the distribution of the residuals. If the residuals are normally distributed, this means that there are no systematic errors in the model and the estimation results are reliable. For this purpose, the distribution of the residuals and their main statistical indicators are analyzed below. We will check whether the residuals have a normal distribution using the Jarque-Bera test.

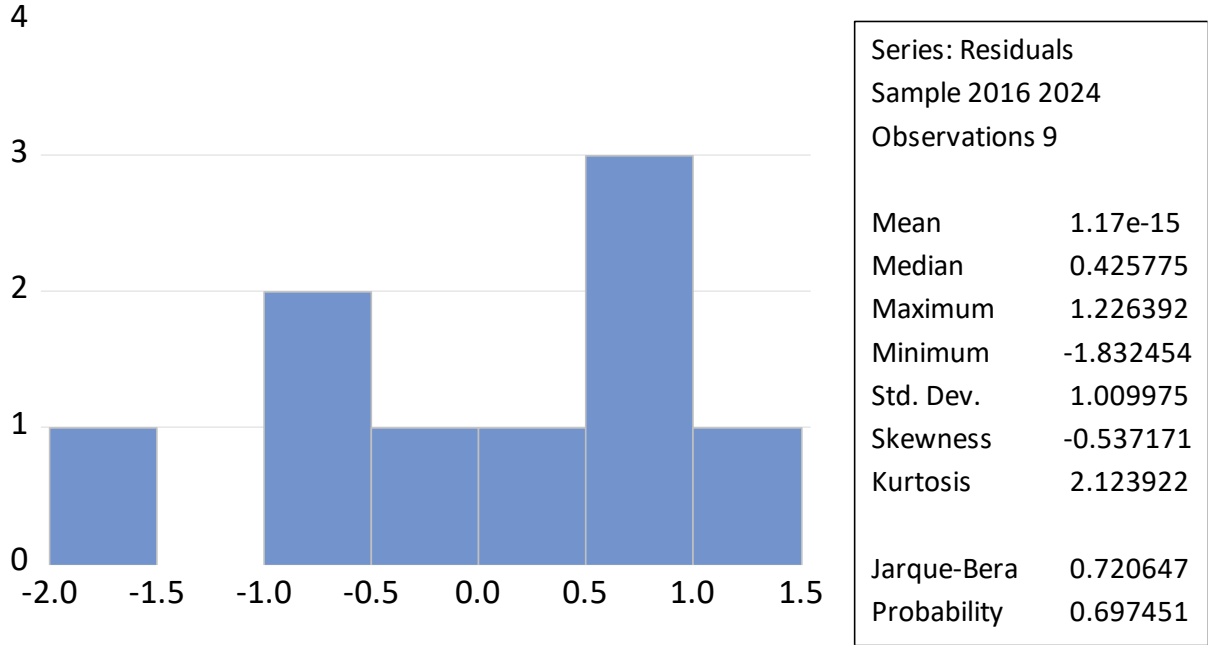


Figure 2. Jarque-Bera test

The presented residuals analysis allowed us to assess the main statistical properties of the model. The mean value of the residuals is 1.17×10^{-15}, which is practically close to zero, indicating that there is no systematic error in the model. The standard deviation of the residuals is 1.009975, which ensures the stability of the dispersion.

The value of the skyness of -0.537171 indicates that the residuals of the model have a slight negative asymmetry, that is, the distribution is slightly "stretched" to the left. The value of the kurtosis (2.123922) is below the level of the normal distribution, indicating that the distribution of the residuals is more compact.

Most importantly, the probability value of the Jarque–Bera test (0.697451) is much higher than the 5 percent significance level. This means that there is no reason to reject the null hypothesis - the assumption that the residuals are normally distributed. Thus, the model meets the conditions of a normal distribution.

In general, the residual analysis is characterized by the adequacy of the model, the fulfillment of the normality condition, and the absence of systematic errors. This allows us to consider the results of the applied model as reliable and scientifically sound.

The econometric analysis conducted clearly showed the impact of tourism infrastructure factors on the flow of foreign tourists. In particular, the significance of investments in infrastructure, hotel capacity, and the number of vehicles was confirmed. The digital services index and political stability indicators also have a certain impact on the dynamics of tourist flows, and it was found that their levels of influence change over time. From a practical point of view, such results indicate the need for integrated infrastructure management, especially the importance of digitalization and the development of transport logistics.

According to the results of the analysis, the main drivers of infrastructure development in Uzbekistan are investments, hotel capacity, and transport infrastructure. Investments directly contributed to the construction of new facilities and the modernization of existing infrastructure. The steady growth of hotel capacity over the years has expanded the operational capabilities of the service market. At the same time, the increase in the number of air and road transport has increased the mobility of tourists within the country.

The results are fully consistent with the investment policy implemented in the country, the facilitations created for the tourism sector, and the processes of infrastructure modernization. For example, the growth of infrastructure investments after 2017 has been parallel to the sharp increase in the number of foreign tourists. A similar dynamic was observed in transport infrastructure, and it was found that the technical expansion of infrastructure coincided with the current traffic flow.

Investments, digital services, and transport infrastructure are also noted as key factors in tourism development in the experience of countries such as China, Turkey, and Kazakhstan. This, in turn, confirms the consistency of the results in Uzbekistan with international trends. For example, Shen et al. (2023) showed that transport infrastructure plays a decisive role in regional tourism, and the results in Uzbekistan also confirm this conclusion. Also, the dynamics observed in the countries of Europe and Southeast Asia in terms of the impact of digital infrastructure are close to the trend in Uzbekistan.

At the same time, there are a number of limitations in the country. First, although the volume of infrastructure investments has grown rapidly, its distribution across regions is not proportional. Second, a number of logistical problems still remain in the transport infrastructure, especially on railway and domestic air routes. Third, although digitalization indicators are growing rapidly, the level of use of TMIS and online services by the population and entrepreneurs is still insufficient. Fluctuations in the political stability

index also remain as a factor partially affecting tourist flows.

Conclusion

Within the framework of this study, an econometric analysis based on OLS was carried out to assess the management of tourism infrastructure in Uzbekistan and its impact on the flow of foreign tourists during 2016-2024. The results of the study made it possible to formulate a number of important scientific conclusions.

The first result was that investments in tourism infrastructure were confirmed as the most important positive determinant of the flow of foreign tourists. Since the increase in investments led to the development of hotels, the transport system, service facilities and digital services, a significant increase in tourist demand was observed. This, in turn, increased economic stability and the multiplier effect in the tourism sector.

According to the second result, hotel capacity had a highly positive impact on the flow of foreign tourists. The number of hotel beds increased by almost 10 times in 2024 compared to 2016, which led to an increase in the quality and convenience of tourist services, and therefore, an expansion of the flow of tourists. This result confirms that the expansion of the infrastructure base in Uzbekistan is one of the important elements of tourist activity.

The third scientific result of the study showed that transport infrastructure, especially the increase in the number of tourist vehicles, is inextricably linked to the flow of tourists. The increase in the number of vehicles from 240 to 3988 in 2016-2024 served to improve efficient logistics, internal mobility, and the speed of reaching destinations.

The fourth important conclusion is that the importance of digital infrastructure is increasing year by year. The development of TMIS, online booking systems, electronic guide services, and digital service platforms had a strong positive impact on the dynamics of tourist flows. The increase in the digital index from 20 to 165 in 2016-2024 indicates that the digitalization of tourist activities has become a new driver of economic growth.

As a fifth result, changes in the price indices of tourist services showed a certain sensitivity to tourist flows. Although price increases partially reduced tourist flows, improvements in infrastructure quality mitigated this impact.

Finally, the importance of political stability was confirmed. Although the decline in the index negatively affected tourist flows in some years, the overall stable political environment and increased security measures ensured the recovery and growth of tourism.

Overall, the study showed that in 2016-2024, tourism infrastructure indicators in Uzbekistan developed rapidly in the context of systemic reforms and, inextricably linked with economic and institutional factors, shaped tourist flows. This once again confirms the strategic importance of infrastructural modernization of the tourism sector in the country.

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CUSTOMER EXPERIENCE MANAGEMENT THROUGH DIGITALIZATION IN TOURISM

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Abstract
This article analyzes the role of customer experience management (CEM) in the digital transformation of the tourism sector. The study examines opportunities to improve service quality and management efficiency in tourism enterprises through the integration of CRM, artificial intelligence (AI), big data, GHRM, and IoT technologies, in line with the goals of the "Digital Uzbekistan 2030" strategy.

Keywords: digital management, customer experience management, CEM, CRM, AI, big data, global human experience management, IoT, sustainable tourism.

Introduction. In the 21st century, the tourism industry is at the center of global competition. Service quality, personalized experiences, and digital solutions have become key factors shaping tourists' decision-making processes. In this context, the concept of customer experience management (CEM) has become an innovative management strategy for tourism enterprises [2], [3].

In recent years, the tourism sector in the Republic of Uzbekistan has undergone fundamental changes. The "Digital Uzbekistan - 2030" strategy [1] envisions the modernization of the country's service sector and the improvement of service quality and management efficiency through the widespread implementation of digital management, CRM systems, artificial intelligence (AI), big data, and chatbots.

Globally, CEM systems are becoming a key tool for ensuring sustainable development and customer loyalty in tourism [4], [5]. Particularly in the post-pandemic period, digital transformation and "green" innovations have become strategic factors ensuring the recovery and competitiveness of the tourism sector [6], [7].

Thus, this article analyzes the theoretical foundations, international experience, and practical recommendations for Uzbekistan in the field of digital customer experience management in tourism.

Literature review. Godovykh and Tasci (2020) [5] interpreted the concept of CEM based on cognitive, affective, sensory, and conative components, integrating the psychological and technological aspects of customer experience in tourism. Buhalis (2022) [4] substantiated the need for personalization and interactivity of service through digital technologies in the "smart tourism" model.

Romanova and Ushenko (2024) [6] concluded that platform management systems (GMS, CRM) in the hotel sector accelerate service delivery by integrating customer information into a single database. Khusniddinova (2025) [7] empirically demonstrated the positive impact of AI-based chatbots on service speed and customer satisfaction in Uzbek tourism. Internationally, Dabaghi et al. (2022) [8] found that CEM systems play a critical role in enhancing customer trust and brand loyalty in medical tourism.

In Bangladesh, Amin et al. (2025) [9] assessed digital transformation as a mechanism for ecotourism recovery during the pandemic.

Furthermore, Al-Mushattat et al. (2025) [10] demonstrated the impact of green human resource management (GHRM) and mobile technologies on tourism sustainability using the example of hotels in Iraqi Kurdistan. In Europe, Gavrilovic and Maksimovic (2018) [11] reported successful results from integrating IoT, recycling, and green marketing with CEM through the Green Innovation model.

In the IIED (2024) global report [12], over 80% of consumers indicated that they prefer environmentally responsible services, demonstrating the emergence of a "green experience economy."

Research Methodology. The study is based on theoretical-analytical and comparative-analytical approaches. The goal is to identify the relationships between digital management and corporate social responsibility (CSR) management systems in tourism, as well as to adapt international experience to the conditions of Uzbekistan.

The following sources were selected as the primary empirical base for the analysis:

- Bangladesh – digital transformation and the green tourism model [9];
- Iraqi Kurdistan – sustainable management through GHRM and mobile technologies [10];
- Europe – green innovations and IoT integration [11];
- Saudi Arabia – AI-based sustainable tourism management [13];
- Global context – reports on participation in the green economy (IIED, 2024) [12].

The analysis method is cross-comparative modeling, i.e., CSR elements (AI, CRM, Big Data, GHRM) are compared in different countries. As a result, an integrative conceptual model was developed.

Analysis and Results. The CEM is based on the digitalization of all stages of customer interaction:

- CRM systems – data integration and personalization;
- AI and chatbots – real-time communication and accelerated service;
- Big data – behavior analysis and forecasting;
- Feedback systems – measuring loyalty and improving service [6], [9].

Based on Uzbekistan's experience, this model is fully aligned with the goals of the "Digital Uzbekistan 2030" strategy, promoting the automation of tourism services and the development of a culture of innovative management [1].

Case Study: Bangladesh – Transition to Sustainable Tourism through Digital Transformation [9]

As a result of the COVID-19 pandemic, Bangladesh faced an acute crisis in the tourism sector: the number of foreign tourist arrivals fell by 72%, thousands of jobs in the industry were lost, and its share of GDP decreased from 4.4% to 2.3% compared to 2019. Therefore, in 2021, the government introduced a new strategy that integrates digital transformation and sustainable tourism policy.

To demonstrate the macroeconomic impact of the tourism sector, the Computable General Equilibrium (CGE) model developed by Amin et al. (2025) was used. The model covers 86 goods and services sectors and evaluates investment scenarios in digital infrastructure, green energy, and local tourism development.

Figure 1. Results from a study by Amin et al.[9]

This integrated approach of the CGE model has proven to be a successful combination of sustainability, digitalization, and efficiency in tourism policy.

The National Payment Platform, created by Bangladesh Bank, integrated e-commerce and reservation systems into a single payment network. This not only provided convenience for tourists but also became a key component of customer experience management (CEM) processes. Other implemented features included:

• E-tourism systems (booking, real-time analytics, feedback analytics),

• IoT-based hotel management,

• Personalization through an AI-powered recommendation system.

After the pandemic, Bangladeshi tourists began to prefer domestic and "green" tourism over long-distance travel. The youth segment has become a leader in "community-based tourism." Thanks to digitalization:

• The number of eco-friendly destinations increased by 20%;

• The share of "eco-friendly" hotels reached 27%;

• Local brands attracted 30% more tourists through digital marketing. Under the CGE model, the government tested digital payments, green grants, and domestic tourism subsidies. The following methods proved to be the most effective:

Table 1.

Results from the CGE model

Policy Measure	Outcome	Change (%)
Digital tourism platforms	Number of domestic tourists	+15.4
AI based services	Customer satisfaction	+18.7
Green tourism investments	CO_2 emissions	−11.2

Bangladesh's experience shows that:

• Integrating CEM with digital payment infrastructure increases customer trust;

• Promoting domestic tourism through digital platforms stimulates the local economy;

• Personalizing services using AI + IoT + CRM technologies ensures environmental and social efficiency.

Saudi Arabia - An AI-Based Sustainable Tourism Model

Saudi Arabia has developed the "AI-Based Sustainable Tourism" concept as part of its Vision 2030 strategy [13]. This model transforms tourism management into an automated and environmentally sustainable system through the integration of artificial intelligence (AI), IoT, and blockchain technologies.

According to the results presented in the journal Information by Alrashid et al. (2024) [13], AI-based systems significantly improved service quality:

• Energy consumption decreased by -18%;

• Service time decreased by -25%

• Guest satisfaction increased by +30%.

The system analyzes tourists' psychological state using emotion mapping (identifying customer emotions) and offers personalized recommendations. Blockchain has increased reliability by creating a secure payment system.

A 24/7 communication and service system using AI-powered chatbots has also been created, becoming a key part of the CEM strategy [13], [4]. As a result, Saudi Arabia has been recognized as the fastest-growing "smart tourism destination" in the region in 2023-2024.

European Union - Integration of "Smart and Green Tourism"

The "smart destination" model, based on IoT and green marketing concepts, is widely used in European countries.

Gavrilovic and Maksimovic (2018) [11] showed in their study in the journal Sustainability that the "green innovation" model resulted in a 22% increase in the energy efficiency of tourism businesses.

Their approach uses IoT sensors to monitor energy consumption in hotels, automate waste management

systems, and provide customers with information about their environmental impact through an environmental feedback mechanism [11]. Using mobile apps, tourists can choose eco-friendly routes through an "eco-reward" system and earn points for environmental responsibility. This approach combines the CEM strategy with sustainable development principles, enhancing service quality and loyalty [5], [11].

As a result, the European Union has achieved a balance of economic sustainability and environmental responsibility in the tourism sector through a combination of a digital CEM strategy and environmental innovation.

Iraqi Kurdistan – Integration of GHRM and Mobile TechnologiesaA study by Al-Mushattat et al. (2025) [10], published in the journal Sustainability, examined the impact of green human resource management (GHRM) and mobile IT technologies on the effectiveness of corporate culture management.

The study was conducted using 25 hotels in Iraqi Kurdistan.

The results:

• service speed increased by 24%;

• customer satisfaction index was 4.25/5 points;

• staff environmental awareness and motivation for service significantly increased [10].

The following mechanisms were implemented using mobile platforms:

• employee-guest feedback system;

• environmental training programs;

• environmental performance assessment (employee environmental performance assessment).

This system improved the effectiveness of corporate culture management by digitizing communication between employees and customers based on the human factor [10], [6].

As a result, GHRM has developed a new, "human-centric" aspect of the CEM concept – an approach that integrates service quality and environmental responsibility.

Table 2

Summary Analysis and Comparative Results

Country	Technological Approach	CEM Strategy	Outcome
Bangladesh	AI, Big Data, CRM	Digital transformation and domestic tourism	Revenue +8.2%, CO_2 –11%
Saudi Arabia	AI, IoT, Blockchain	Smart personalization	Satisfaction +30%, time –25%
European Union	IoT, Green CRM	Eco-feedback system	Energy +22%, loyalty +15%
Iraq Kurdistan	GHRM, Mobile IT	Human-centered CEM	Satisfaction 4.25/5, speed +24%

The international report "Tracking Engagement in the Global Green Economy," published by IIED and Savanta (2024) [12], provides an in-depth analysis of the tourism industry's role in engaging in the green economy. The study covers 36 countries, including Uzbekistan, Bangladesh, Saudi Arabia, Germany, and Japan, and analyzes sustainable tourism practices and customer experience management (CEM).

According to the report:

• More than 80% of consumers worldwide consider environmental responsibility and green innovation key criteria when choosing services;

• 56% of tourists are willing to pay an average of 15% more for "green" brands;

• The term "green experience economy" is defined as an emerging economic concept that reflects the integration of customer experience with environmental values in tourism [12]. The IIED report proposes a four-stage model for the concept of green customer experience management (CEM) in green tourism:

Table 3

4-Stage Model of the Green Customer Experience Management Concept

Stage	Description	Technological Basis
Awareness	Developing customers' environmental awareness	Green marketing, IoT banners
Engagement	Involving customers in ecological activities	Mobile applications, loyalty gamification
Transformation	Adapting services to green standards	AI analytics, CRM integration
Retention	Increasing eco-tourists' loyalty	Big Data feedback, digital storytelling

According to this model, CEM serves not only as a tool for managing customer experience but also as a strategic mechanism for stimulating green economic activity.

The "Green Experience Economy" concept proposed in the IIED report envisions a reshaping of tourism based on a triad of environmental values, digital transformation, and customer experience. This approach is recognized as an evolutionary stage of the CEM model.

Based on an analysis of international experience, the following integrative model is proposed for successfully combining CEM and digital management:

Table 4.

CEM and the integrative model of digital management

Component	Technological means	Expected result
CRM & AI	Data analytics, chatbots	Speed of service, personalization
GHRM & IoT	Green management, energy control	Eco-efficiency
Big Data & Feedback	Realistic analysis of customer opinion	Loyalty and trust
Digital Strategy	National policies and standards	Innovative management system

This model can serve as a foundation for developing sustainable and customer-centric management through digital ecosystems in Uzbek tourism.

Conclusions and Recommendations.

The study results showed that customer experience management (CEM) is becoming a key focus of digital transformation in the tourism sector. This concept is recognized as a strategic tool for improving service quality, personalization, building loyalty, and strengthening brand trust.

1. The CEM system has proven itself to be a strategic management model for improving service quality, personalization, and loyalty in tourism. The study demonstrated that by integrating the stages of customer interaction—information acquisition, booking, service provision, and after-sales service (feedback)—into a single ecosystem using digital technologies, the tourist's subjective experience significantly improves. CEM not only manages the service process but also integrates the customer's emotional, cognitive, and environmental values into the tourism system.

2. The integration of digital management tools (CRM, AI, big data, and GHRM) enables the automation of service processes, increasing speed and reliability. CRM systems simplify the collection and segmentation of customer data, AI-based chatbots provide 24/7 service, big data predicts tourist behavior, and GHRM manages employee activities based on environmental and humanitarian principles. The synergy of these tools results in customer interaction processes becoming a management model based on digital culture.

3. International experience (Bangladesh, Iraqi Kurdistan, Saudi Arabia, and the European Union) has demonstrated the versatility and flexibility of the CEM concept. While in Bangladesh, digital transformation and the green tourism model ensure sustainability based on CGE (computable general equilibrium) [9], in Iraqi Kurdistan, the GHRM policy has improved service quality and environmental awareness [10]. Saudi Arabia has developed a "smart tourism" system through the integration of AI, IoT, and blockchain [13], while the "Smart & Green Destination" concept in the European Union has improved energy efficiency and strengthened environmental sustainability [11]. This experience could be an important resource for Uzbekistan in developing a "smart-green-digital" model.

4. When a sustainable tourism ecosystem is combined with digital innovation, it simultaneously promotes economic growth and environmental responsibility. Green technologies, digital payment systems, AI-based analytics, and "environmental feedback" systems will shape tourism not only as a source of revenue but also as a platform for social and environmental development.

Based on the above, we offer the following practical recommendations:

• Implementation of AI-based CRM systems. It is necessary to widely implement artificial intelligence tools in tourism enterprises to automatically analyze customer data, anticipate needs, and provide personalized services.

• Formulation of GHRM policies. • Training employees based on environmental values, implementing a "green performance assessment" system, and instilling sustainable development principles in the service sector.

• Establishing big data processing centers. Integrating databases into tourism and digitalizing industry monitoring through the UzTourData platform.

• Implementing IoT technologies. Improving customer convenience through smart hotels, intelligent transport systems, and digital security solutions.

• Expanding international cooperation. Collaborating with the WTO, IIED, and other international organizations on digital sustainable tourism programs, implementing best practices through grants and innovative projects.

Thus, managing customer experience through digital management is viewed as a strategic direction that strengthens the competitiveness, sustainability, and international image of Uzbek tourism. This model will enable the country to develop an innovative, environmentally friendly, and people-centered management system in the tourism sector, thereby realizing the goals of the "Digital Uzbekistan 2030" strategy.

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DISTINCTIVE FEATURES OF SUSTAINABLE TOURISM DEVELOPMENT

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Abstract
This article examines the distinctive characteristics of sustainable tourism development. The concept of sustainable tourism is analyzed in terms of its economic, social, and environmental dimensions, while recent trends in both Uzbekistan and global tourism are scientifically compared. The study analyzes global and national tourism performance in the pre- and post-COVID periods using indicators such as economic growth, employment generation, the expansion of ecotourism, and the increasing number of environmentally certified "green" hotels. In addition, the article also provides strategic recommendations for the development of sustainable tourism.

Keywords: ecotourism, green development, golden year of travel, environmental responsibility

Introduction. Today, it is no exaggeration to consider that tourism has been becoming one of the key sectors of the global economy. Because the concept of tourism is not just a term that implies the population's travel and recreation, but is also considered a sector that occupies a significant share in the GDP of countries, and therefore its sustainable development has become a matter of great importance.

The concept of sustainable tourism is interpreted differently in different literature. According to Australia's National Ecotourism Strategy, which is considered to be partly close to our worldview, ecotourism is defined as nature-based tourism. Similarly, the International Union for Conservation of Nature (IUCN) describes ecotourism as "responsible travel focused on experiencing and appreciating nature in a way that contributes to environmental conservation, enhances the well-being of local communities, and supports the protection of natural resources"[1].

Furthermore, the report "Making Tourism More Sustainable – A Guide for Policy Makers," jointly prepared by the United Nations World Tourism Organization (UNWTO) and the United Nations Environment Programme (UNEP) in 2005, defines "sustainable tourism" as tourism that takes into account current and future economic, social, and environmental impacts, while addressing the needs of tourists, industry stakeholders, and host communities[2].

Based on these interpretations, we can conclude that sustainable tourism is a form of tourism that maintains a balance among economic, environmental, social, and cultural development. It promotes the rational use of environmental resources, in which part of the funds received from tourism development are directed to the restoration of tourism resources and the improvement of tourism service production technologies, as well as the increasing number of tourists in an environmentally demanding environment. It is a type of tourism that aims to address the growing conflict between meeting human needs and the limited amount of natural, social and economic resources[3].

In 2024, the tourism sector accounted for nearly 10% of global gross domestic product, amounting to approximately USD 10.9 trillion[4]. The financial footprint of the Travel and Tourism industry reached one of the highest levels in its history, fully recovering—and even slightly surpassing the "golden year of travel" of 2019 (the pre-pandemic period). According to forecasts, by 2034 the sector could represent 11.4% of the global economic landscape, contributing nearly USD 16 trillion to the world economy.

The rapidly expanding tourism industry is also expected to play a crucial role in employment generation, providing jobs for approximately 449 million people worldwide. This highlights the strategic importance of travel and tourism in global employment, with the sector projected to account for around 12–13% of total global labor market[5].

Such optimistic global growth forecasts are encouraging Uzbekistan to focus more on tourism development. By effectively utilizing its rich natural and cultural heritage, our country aims to transform tourism into one of the key drivers of economic growth. As emphasized by the President of the Republic of Uzbekistan, Shavkat Mirziyoyev, during his address at the "Sustainable Development Week" Summit in Abu Dhabi: "The strategic objective of the New Uzbekistan is to ensure environmental sustainability and transition to a 'green' development model based on resource-efficient economic growth. Therefore, we have declared 2025 as the "Year of Environmental Protection and the "Green Economy" in Uzbekistan."[6]

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[6] https://www.xs.uz/uz/post/shavkat-mirziyoev-abu-dabi-barqaror-rivozhlanish-haftaligi-sammitida-nutq-sozladi?utm

In addition, the simplification of the visa regime, such as the introduction of an automated system for issuing electronic entry visas, the abolition of the visa requirement for citizens of a number of countries as transit tourists, and the increase in the number of tourist-class vehicles are decisive factors in the increase in the tourist flow to Uzbekistan[7].

Literature Review. As the demands of tourists increase, the problem of stabilizing tourism is becoming increasingly urgent. According to A. Ursul, a sustainable (balanced) development strategy requires not only the consideration of economic and environmental dimensions but also the systematic optimization of all parameters and trends within the socio-natural system, aiming to achieve harmony between individuals, society, and nature. From his perspective, the sustainability of economic growth and social development should be achieved without unreasonable degradation of nature, primarily by preserving the biosphere of our planet[8].

E. Qiyaqbayeva (2015)[9] conceptualizes sustainable tourism development as a long-term process based on the harmonization of social, economic, environmental and cultural goals for present and future generations.

In examining the types of tourism such as "environment-sensitive" and "environment-dependent" tourism, C. Aall (2014) distinguishes between two contrasting approaches to the "environment"[10]. The former refers to tourism practices aimed at minimizing negative environmental impacts, while the latter views the environment primarily as a resource base to be utilized for tourism activities.

E. Grechishkina identifies four types of sustainability in the tourism industry: very weak (tourism imperative scenario); weak (tourism product scenario); strong (ecological tourism scenario); very strong (neotenic tourism scenario)[11].

K. Arbuzova considers sustainable development of tourism as long-term development, in which a balance is achieved in the implementation of economic, environmental, social and cultural development goals[12].

Methodology. This scientific research is based on a multidisciplinary and analytical approaches, allowing for a comprehensive and in-depth study of the specific aspects of sustainable tourism development. The article studied and analyzed data and reports published by the World Tourism Organization (UNWTO), the International Union for Conservation of Nature (IUCN), the United Nations Environment Program (UNEP), and a number of similar international organizations.

Key global factors influencing sustainable tourism development were identified and evaluated. In addition, the experiences of foreign countries with well-developed ecotourism models were compared with Uzbekistan's tourism sector in order to determine advanced strategic approaches suitable for our Republic of Uzbekistan. Statistical data related to tourism's contribution to global GDP and investment volumes were also analyzed.

Based on international forecasts for the period 2023–2034 published by the World Travel & Tourism Council (WTTC), conclusions were drawn regarding Uzbekistan's position within global tourism trends. Furthermore, a wide range of academic articles, international reports, government policy documents, and strategic programs relevant to the research topic were also studied in detail.

Results and Analysis. The results obtained during the study clarified the global state of the tourism industry and the directions of its sustainable development in the case of Uzbekistan. In recent years, tourism has become an integral component of global economic activity. Notably, in the post-pandemic period, not only recovery, but also new growth trends are observed in this sector.

According to data from international organizations, tourism's contribution to the global economy continues to increase, further reinforcing its strategic importance[13]. Against the background of these general changes, it is important to analyze the dynamics of global and national indicators.

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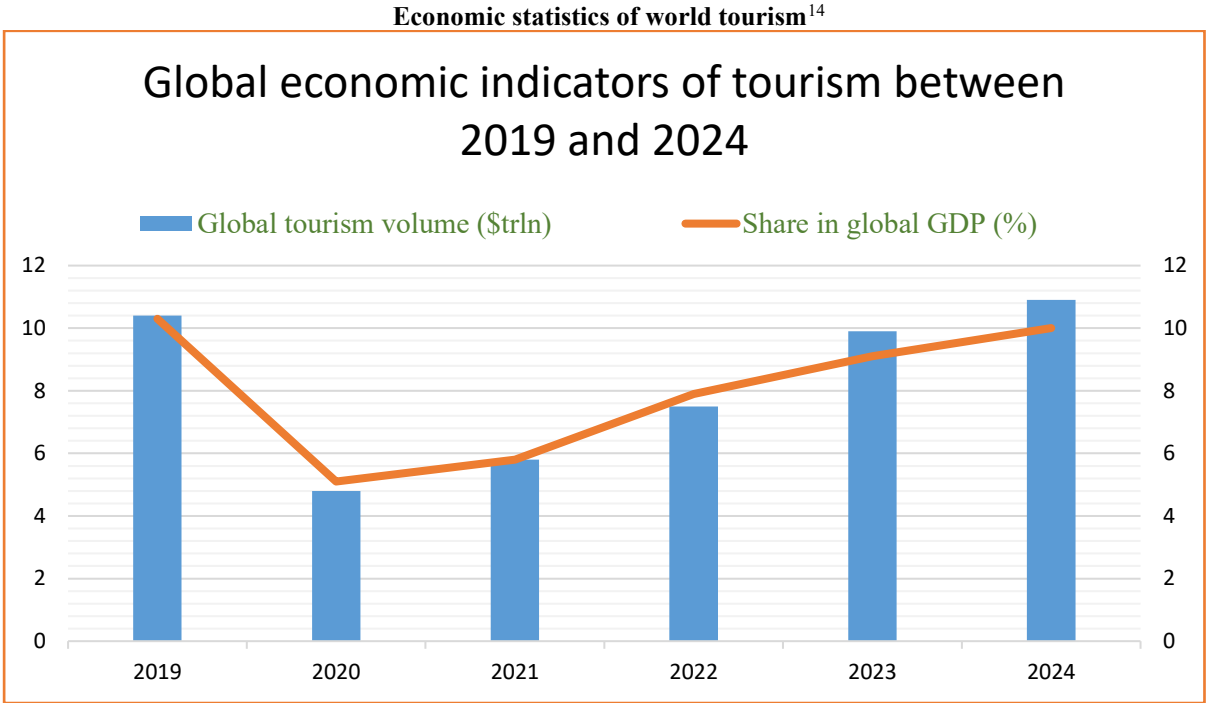
Picture 1

Economic statistics of world tourism[14]



As illustrated in the above presented figure, the period from 2019 to 2024 witnessed significant fluctuations in the economic performance of the global tourism sector. In 2019, the overall value of the tourism industry was estimated at approximately USD 10 trillion, accounting for nearly 10 percent of global gross domestic product.

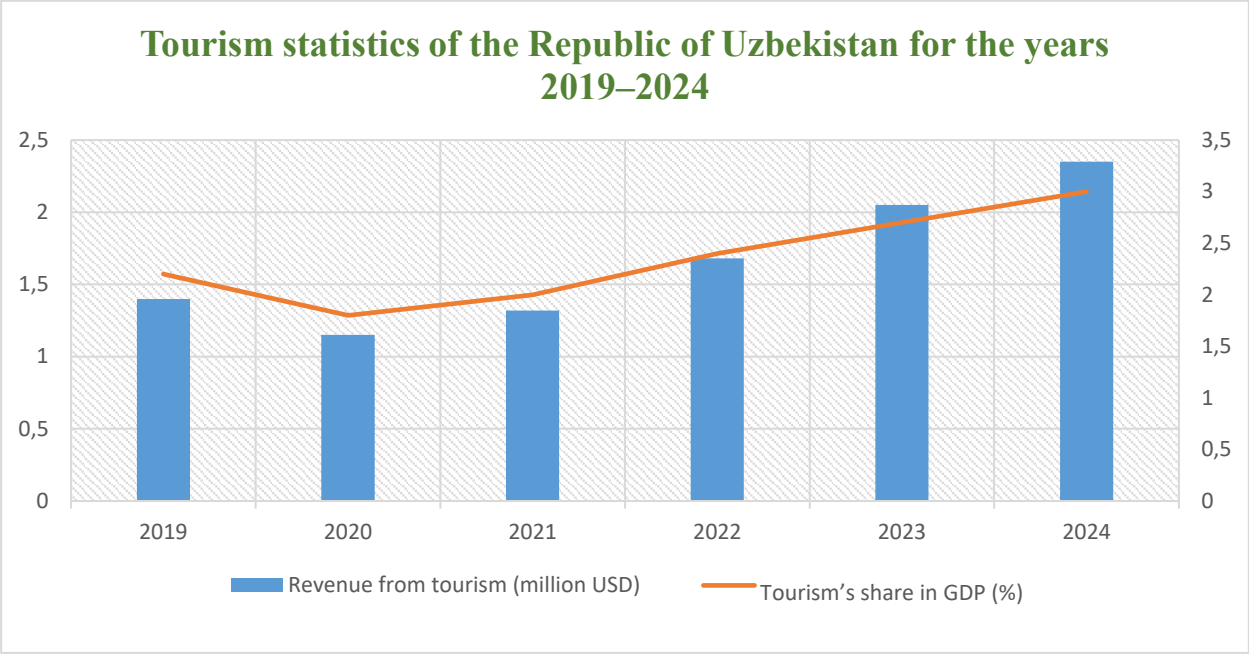
In 2020, however, due to the impact of the COVID-19 pandemic, these indicators experienced a sharp decline: tourism volume almost halved, while its contribution to global GDP fell to around 5 percent. Despite this severe downturnthe recovery process continued significantly in subsequent years. In 2021–2024, the volume of global tourism gradually increased, approaching $ 11 trillion in 2024[15]. At the same time, the sector's share in global GDP returned to levels comparable to the pre-pandemic period.

Against the background of the above global trends, it is encouraging to observe that Uzbekistan's tourism sector has also demonstrated notable growth dynamics. Over the period from 2019 to 2024, both the number of tourists visiting our country and tourism revenues have increased steadily. According to official statistics, the number of visitors to Uzbekistan reached 8.2 million in 2024. The table below presents key indicators of Uzbekistan's tourism performance for the years 2019–2024.

[14] United Nations World Tourism Data Portal. https://www.unwto.org/statistics
[15] World Bank (2024). Global Economic Prospects: Tourism and Service Recovery.

Picture 2

Economic indicators of tourism in Uzbekistan[16]



The year 2019 is commonly regarded as the "golden year of travel," representing the pre-pandemic baseline for the tourism industry. As observed across many countries, the impact of the COVID-19 pandemic was also reflected in Uzbekistan's tourism revenues (tourism revenues amounted to $1.15 billion and its share in the country's GDP was 1.8%).

Between 2021 and 2024, the sector experienced a gradual recovery. The industry gradually recovered in 2021–2024, and in 2024 revenues exceeded pre-pandemic levels, reaching 3% of GDP[17].

Since the results of this analysis are presented only from the economic side, below we also consider separately the social and environmental sustainability indicators of Uzbek tourism. For this purpose, two key reference points were selected: the pre-pandemic year of 2019 and the most recent stage of development in 2024.

Table 1

Social and Environmental Sustainability Indicators of Tourism in Uzbekistan (2019 and 2024)

Indicator	2019	2024	Growth / Change (%)
Number of people employed in the tourism sector (thousands of people)[18]	110	135	+22,7 %
Average monthly income from tourism services (USD)	450	580	+28,9 %
Ecotourism facilities (number of national parks, reserves, eco-routes)	10	17	+70 %
Number of hotels with "green" certification[19]	15	48	+220 %
Local residents' participation in domestic tourism activities (%)	40	55	+15 p.p.
Tourism-related CO_2 emissions (million tons)[20]	1.3	1.1	−15 %

The indicators for 2019–2024 presented in the table show that tourism in the Republic of Uzbekistan is entering a new optimal stage of sustainable development. The figures prove that the social and environmental components of the industry have significantly improved in recent years. In particular, the 22% increase in the number of local residents employed in the tourism sector (from 110 thousand to 135 thousand people) further increases the importance of this sector in the economy and has a positive impact on the well-being of the local population. At the same time, the increase in average income from tourism services by almost 130 US dollars indicates an improvement in the efficiency and quality of service in the industry.

Environmental performance indicators are equally noteworthy. The threefold increase in the number of "green"-certified hotels indicates that the tourism infrastructure is based on environmentally responsible principles. Moreover, the expansion of national parks, pro-

[16] O'zbekiston Respublikasi Statistika agentligi. Turizm statistik to'plami 2019–2024. Toshkent, 2025.
[17] O'zbekiston Respublikasi Iqtisodiyot va moliya vazirligi ma'lumotlari, 2024.
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[19] O'zbekiston Turizm qo'mitasi. Yashil mehmonxonalar reyestri. Toshkent, 2024.
[20] Ekologiya, atrof-muhitni muhofaza qilish va iqlim o'zgarishi vazirligi. CO_2 chiqindilari monitoringi hisobotlari, 2024.

tected areas, and eco-routes points to the rapid development of ecotourism as a key segment of the industry. Another encouraging fact is that carbon emissions associated with the tourism sector have decreased by 15 percent.

Overall, the findings for the 2019–2024 period indicate that Uzbekistan is pursuing a comprehensive tourism policy that combines economic growth with environmental sustainability. In the following section, we can assess the position of our country in world tourism by comparing Uzbekistan's progress in sustainable tourism with global trends:

Table 2

INDICATORS OF SUSTAINABLE DEVELOPMENT IN GLOBAL AND UZBEK TOURISM (2019–2024)

DIRECTION/INDICATOR	2019 (GLOBAL)	2024 (GLOBAL)	GROWTH (%) (GLOBAL)	2019 (UZB.)	2024 (UZB.)	GROWTH (%) (UZB.)
ECOTOURISM (NUMBER OF FACILITIES / PERCENTAGE)	18%	25%	+39	10	17	+70
DIGITAL / SMART TOURISM	9%	15%	+66	5%	9%	+80
CULTURAL TOURISM	22%	27%	+23	35%	38%	+8,5
HEALTH AND WELLNESS TOURISM	14%	19%	+36	7%	12%	+71
RURAL / AGRO TOURISM	7%	11%	+57	2%	5%	+150
CO_2 EMISSIONS (MILLION TONS)	1,3	1,1	−15	1,3	1,1	−15

Table 2 demonstrates that Uzbekistan's tourism sector has outperformed global tourism growth dynamics in most dimensions, surpassing the growth dynamics of world tourism. In particular, the gap between global and national growth rates in ecotourism and rural/agro-tourism serves as a clear illustration of this trend. While ecotourism expanded globally by approximately 39 percent, Uzbekistan recorded growth of nearly 70 percent. A similar pattern is observed in rural and agro-tourism, where global growth reached 57 percent, compared to an impressive 150 percent increase in Uzbekistan. These figures strongly support the conclusion that the country's tourism development trajectory is gaining momentum at a faster pace than global averages. Also, while digital or smart tourism increased from 9% to 15% globally, in Uzbekistan it increased from 5% to 9%, representing an increase of 80%. This confirms the rapid modernization of the tourism sector through the introduction of digital services and technological solutions[21]. While cultural tourism increased from 22% to 27% globally, in Uzbekistan it reached 35% to 38%, showing a relatively lower growth (8.5%).

Health and wellness tourism has increased from 14% to 19% globally, and in Uzbekistan, it has grown from 7% to 12%, with a growth rate of 71%. This shows that the work being done in the field of wellness services and resorts is yielding effective results. As for CO_2 emissions, both globally and in Uzbekistan, they have decreased from 1.3 million tons to 1.1 million tons (−15%)[22]. The conclusion from the figures in the table is that Uzbekistan is successfully making efforts to catch up with the global level in terms of economic, environmental and technological sustainability of tourism. However, it seems that our country is not fully utilizing the existing opportunities in some areas. In our opinion, higher levels can be achieved by expanding digital infrastructure, increasing human resources, developing cultural tourism in modern forms, and strengthening the ecological approach. Based on these considerations, the following recommendations are proposed:

1. **Enhancing ecotourism and "green" standards.** Establish an ecological certification system for tourist facilities, further promote zero-waste tourism, and the use of renewable energy sources.
2. **Reinvigorating cultural heritage through innovation.** Develop digital museums, virtual tours, and interactive cultural experiences.
3. **Improving human capital and service quality.** Ensure that industry representatives are trained in accordance with international standards.
4. **Expanding digital infrastructure.** Promote smart tourism solutions, including online booking platforms, mobile applications, and integrated digital travel services.
5. **Developing medical and wellness tourism.** Modernize recreational and therapeutic facilities in areas rich in natural resources in accordance with global demand and launch extensive promotional activities to inform tourists about them.

In general, sustainable tourism development policies should not be limited to focusing only on economic growth, but should also be aimed at maintaining ecological balance and improving the well-being of local populations. International experience shows that an innovative approach, environmental responsibility and social cooperation contribute to the long-term sustainable development of tourism.

Conclusion. The results of this study indicate that, although the unexpected shock of the COVID-19 pandemic, following the "golden year" of tourism in 2019, caused a severe disruption not only to Uzbekistan's tourism industry but also to global tourism as a whole,

[21] World Bank. *Tourism and Digitalization Report*, 2024.

[22] UNWTO. World Tourism Barometer, 2024

the sector demonstrated a remarkable capacity for recovery within a relatively short period. The statistical evidence presented confirms that by 2024, tourism indicators not only reached pre-pandemic levels but in several cases exceeded those recorded in 2019.

The figures show that Uzbek tourism is developing in line with the principles of global sustainability and is implementing responsible programs not only on the economic front, but also on the social and environmental front. At the same time, certain structural shortcomings were identified, and context-specific recommendations were proposed based on national conditions. It is expected that the implementation of these measures will further strengthen Uzbekistan's position in the international tourism market and serve as a foundation for the country's long-term sustainable tourism development.

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MEDICAL SCIENCES

STUDY OF THE EFFECT OF SULODEXIDE ON THE STATE OF ENDOTHELIAL DYSFUNCTION IN PATIENTS WITH ISCHEMIC HEART DISEASE HISTORY OF MYOCARDIAL REVASCULARISATION

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Abstract
The article presents the results of a study devoted to investigating the effect of sulodexide on endothelial function in patients with ischaemic heart disease who have undergone myocardial revascularisation. Patients with stable angina pectoris, with and without type 2 diabetes mellitus, were examined. Endothelial function was assessed based on cuff test data and levels of endothelin-1, interleukin-6, and VEGF. It was shown that patients with diabetes mellitus had a higher severity of endothelial dysfunction. A 6-month course of sulodexide therapy improved endothelial function and reduced laboratory markers of inflammation. The data confirm the efficacy and safety of sulodexide in the complex therapy of patients with IHD.

Keywords: ischaemic heart disease; endothelial dysfunction; sulodexide; type 2 diabetes mellitus; endothelium-dependent vasodilation; endothelin-1; VEGF; interleukin-6; cuff test; reactive hyperaemia**.**

Relevance. Cardiovascular diseases (CVD) remain the leading cause of mortality and disability in both economically developed countries and countries with economies in transition. According to an analysis of overall mortality by region in the Republic of Uzbekistan for 2021, there were 174,541 deaths, of which 61.5% were due to diseases of the circulatory system [1, 2, 3].

In patients with ischaemic heart disease (IHD) and diabetes mellitus (DM), the ability of endothelial cells to synthesise nitric oxide (NO) and release vasorelaxing factors is reduced, while the production of vasoconstrictive substances is maintained or even increased. This results in an imbalance between the mediators that ensure normal endothelial function, which manifests itself in the development of endothelial dysfunction (ED) [4].

The main manifestations of ED include impaired endothelium-dependent vasodilation and increased adhesive properties of the vascular lining. Coronary artery endothelial dysfunction is accompanied by a decrease in coronary reserve and the inability of blood vessels to dilate adequately when myocardial oxygen demand increases, which contributes to the onset and progression of ischaemia [5, 6]. Endothelial dysfunction is characteristic of patients at risk of developing coronary atherosclerosis, and in patients already diagnosed with IHD, it becomes an important marker of cardiovascular events (CVEs).

In recent years, there has been growing interest in the study and treatment of ED. There are many methods

for diagnosing it, but the cuff test is considered the most non-invasive. Tatsuya Maruhashi et al. investigated the effectiveness of this method in Japanese individuals [7], while Ernesto Dallia et al. used it to assess the severity of ED in patients with risk factors for coronary artery disease and acute myocardial infarction [8]. In their study, the worst cuff test results were observed in patients with acute myocardial infarction.

In addition to instrumental methods, laboratory markers play a significant role in the assessment of ED. Among them, endothelin-1 (ET-1), vascular endothelial growth factor (VEGF) and interleukin-6 (IL-6) are of particular importance, as their levels reflect the severity of endothelial dysfunction.

Given the high prevalence of ED, particular attention is paid to the search for pharmacological agents capable of improving endothelial function. Salma Charfeddine et al. demonstrated the positive effect of sulodexide in patients with IHD against the background of COVID-19: the drug contributed to a significant improvement in endothelial function, a reduction in the frequency of angina attacks and a decrease in tachycardia [9].

In this regard, our study aims to investigate the effect of sulodexide on endothelial function in patients with IHD, both with and without diabetes mellitus.

Research objective. To investigate the effect of sulodexide on arterial endothelial function in patients with IHD, depending on the presence of type 2 diabetes mellitus.

Materials and methods. The study included 70 patients with ischaemic heart disease (IHD) and stable exertional angina of functional class (FC) I–IV, who had a history of surgical or endovascular myocardial revascularisation — coronary artery bypass grafting (CABG) or percutaneous coronary intervention (PCI) — more than one year ago.

As a control group (CG), 20 practically healthy individuals with no clinical signs of cardiovascular pathology were examined.

All patients in the main group were divided into two subgroups depending on the presence of type 2 diabetes mellitus (T2DM):

• Group 1 — 36 patients without T2DM;

• Group 2 — 34 patients diagnosed with T2DM.

All patients examined had stage III arterial hypertension (AH) and chronic heart failure (CHF) of functional class I–III according to the New York Heart Association (NYHA) classification.

Exclusion criteria included patients:

• with a high risk of bleeding;

• who had undergone myocardial revascularisation less than 1 year prior to inclusion;

• receiving dual or triple antiplatelet therapy;

• with gastric or duodenal ulcer;

• with a history of acute cerebrovascular accident;

• with atrial fibrillation requiring oral anticoagulants;

• with a history of haemorrhoidal bleeding episodes.

All patients received standard drug therapy, including acetylsalicylic acid (75 mg/day), statins, β-blockers, angiotensin-converting enzyme inhibitors or sartans, and mineralocorticoid receptor antagonists.

When comparing baseline clinical and laboratory parameters, both groups were comparable in terms of age, blood pressure, and body mass index (BMI) (Table 1). Significant differences were found in fasting blood glucose, glycated haemoglobin (HbA1c) and creatinine levels (Table 1). The clinical and laboratory characteristics of the patients examined are presented in Table 1.

Table 1.

Clinical and laboratory characteristics of the patients examined.

Index	**1 group (non DM)**	**2 group (with DM)**	**Control group**
Age, years	65,49±1,05	65,86±1,24	42,37±2,64**
BMI, kg/m²	29,79±0,86	29,89±0,49	22,35±0,32*
SBP, mmHg	138,16±25,35	138,27±6,26	118,41±5,22*
DBP, mmHg	77,74±9,73	78,33±3,06	70,26±4,18*
HbA1, %	5,19±0,14	7,53±0,28^^	5,23±0,12*
Glicemia, mmol/l	5,22±0,12	8,79±0,53^^	5,02±0,15*
EF, %	53,18±6,20	51,56±6.87	64,85 ± 4,91*
CABG in anamnes , n	7 (19,4%)	9 (26,5%)	-
TCI in anamnesis, n	29 (80,6%)	25 (73,6%)	-

Note: difference between the main group and GC: * - $p<0.05$, ** - $p<0.01$; difference between main groups I and II: ^- $p<0.05$, ^^- $p<0.01$

All examined patients underwent a comprehensive clinical and instrumental examination, including assessment of anthropometric parameters (body weight, kg; height, cm; body mass index — BMI, kg/m²), blood pressure (BP) measurement, and laboratory tests (fasting blood glucose, mmol/l; lipid spectrum indicators, mmol/l).

The state of vascular endothelial function (EF) was assessed based on a combination of laboratory and instrumental data. In particular, the levels of endothelin-1 (ET-1), interleukin-6 (IL-6) and vascular endothelial growth factor (VEGF) in blood serum were determined, and Doppler ultrasound of the brachial artery (BA) was performed.

For instrumental assessment of EF, a reactive hyperemia test (cuff test) was used according to the method of D. Celermajer et al. (1992). The diameter of the right brachial artery (RBA) was measured using a Philips Affinity 50G ultrasound machine (USA) with a 7 MHz linear probe in B-mode according to generally accepted standards. The artery was visualised in a longitudinal section 2–15 cm above the elbow bend, with the image synchronised with the R wave of the electrocardiogram (ECG). The study was conducted in triplex mode.

At baseline, the diameter of the artery and maximum blood flow velocity were recorded. Doppler ultrasound was performed in the morning, on an empty stomach, with the patient lying on their back, after a 10-minute rest.

To induce reactive hyperemia, a sphygmomanometer cuff was applied to the shoulder, inflating it to a pressure 50 mm Hg above systolic pressure. The cuff was held for 5 minutes, after which the air was quickly released. In the first 15 seconds after decompression, blood flow velocity (BFV) was measured, and during the following 60 seconds, changes in artery diameter were recorded.

The following indicators of brachial artery endothelial function were assessed:

• D_0 (cm) — artery diameter at rest;

• D_1 (cm) — artery diameter after reactive hyperaemia (RH) test;

• V_{max} (cm/s) — peak systolic blood flow velocity;

• V_{min} (cm/s) — maximum diastolic velocity;

• IR (u.e.) — resistance index.

Endothelium-dependent vasodilation (EDVD) was calculated using the formula:

$EDVD = (D_1 – D_0) / D_0 \times 100\%$.

An increase in brachial artery diameter of more than 10% was considered preserved EVD, while an increase of less than 10% indicated impaired endothelial vasomotor function.

Endothelin-1, VEGF, and IL-6 levels were determined by quantitative enzyme-linked immunosorbent assay. VEGF concentration was determined in serum obtained from peripheral venous blood. Blood was collected in the morning on an empty stomach in the supine position after 10 minutes of rest, from the cubital vein, using a vacuum tube. Excessive physical activity was excluded the day before. The blood was centrifuged to obtain serum. VEGF and IL-6 concentrations were measured by solid-phase enzyme-linked immunosorbent assay using the VEGF-IFA-BEST reagent kit manufactured by Vector-Best CJSC (Russia). The concentration of ET-1 was measured by solid-phase enzyme-linked immunosorbent assay using a set of reagents from Elabscience (USA).

After initial examinations, all patients were prescribed sulodexide (Vessel Due F, Catalent Italy, S.P.A. (Italy)) in oral form at a dose of 500 LE/day, divided into 2 doses for a period of 6 months. Six months after treatment with sulodexide, repeat laboratory and instrumental examinations were performed. In order to monitor the safety of sulodexide use, all patients underwent coagulogram assessment and platelet aggregation analysis after 1 and 3 months of treatment with the drug. No cases of haemorrhagic complications were recorded during the study.

Results.

When analysing the functional state of the vascular endothelium in the examined patients, the indicators of endothelium-dependent vasodilation (EDVD) of the brachial artery (BA) deserve special attention (Table 2).

The initial diameter of the BA in patients of both groups did not differ statistically significantly and was 0.45±0.01 cm in patients of group 1 and 0.44±0.01 cm in patients of group 2.

In patients in group 1 (without diabetes mellitus), the PA EVSD index was 7.76±1.7%. In 44.4% (n=16) of patients in this group, the vasomotor function of the endothelium was preserved (EVSD >10%). Endothelial dysfunction (ED) was diagnosed in 20 (55.6%) patients, of whom:

• 10 (27.8%) had insufficient PA diameter increase (EZVD <10%),

• 7 (19.4%) had no diameter increase,

• 3 (8.4%) developed pathological vasoconstriction.

In the second group, which included patients with diabetes mellitus (DM), vasomotor ED induced by shear stress was detected in all cases. The average EED index in this category of patients was 4.8±1.29%. At the same time:

• 17.6% (n=6) of patients had an increase in PA diameter >10%;

• 44.2% (n=15) had impaired vasomotor endothelial function in the form of an insufficient vasodilatory response (<10%);

• 23.5% (n=8) had no increase in diameter;

• 14.7% (n=5) had pathological vasoconstriction.

Doppler examination of linear blood flow velocity parameters (Vmax and Vmin) revealed no significant differences between the groups. However, the degree of increase in velocity characteristics after the reactive hyperemia test was significantly higher in patients in group 1, indicating a decrease in vasodilator reserve in patients in group 2.

In the control group, the PA ESVD index was 20.2±1.23% ($p<0.01$). After removing the compression during the cuff test, a significant increase in blood flow velocity parameters (Vmax, Vmin) was noted compared to patients in group 2 ($p<0.01$). Patients in group

1 also showed a significant increase in velocity parameters, but the severity of the changes was less than in the control group (Table 2).

Table 2.

Baseline indicators of the reactive hyperemia test in the main group (with SD), the comparison group (without SD), and the control group (practically healthy individuals)

Index	CHD non DM		CHD with DM		Control group	
	Before	After	Before	After	Before	After
Diameter a. brachialis, sm	0,45±0,01	**0,49±0,01***	0,44±0,01	0,46±0,01	0,44±0,01	0,53±0,01
Vmax, sm/sec	66,1±3,14	**77,3±3,87***	71,9±1,69	74,6±2,38	74±1,66	**95±1,85****
V min, sm/sec	7,41±0,25	**9.14±0,38***	8,58±0,51	8,8±0,62	7,5±0,19	**10,1±0,33***
RI, y.e.	0,77±0,01	0,75±0,011	0,8±0,015	0,77±0,013	0,65±0,012	0,6±0,013
Endothelium-dependent vasodilation, %	**7,76±1,7°**		4,8±1,29		**20,2±1,23^^^**	

Note: significance of differences between initial and post-trial indicators: *- p<0.05, **- p<0.01; the difference between the indicators in the main group and the control group is significant ^^^ -p<0.001; the difference between the initial indicators of the main groups I and II: ° - p<0.05

When studying baseline laboratory indicators assessing endothelial function in patients with and without diabetes, a significant increase in IL-6, ET-1, and VEGF indicators was noted compared to the control group (p<0.001) (Table 3). When comparing laboratory parameters in patients from the two main groups, a more significant increase in ED parameters was noted in patients with DM. For example, IL-6 in patients in group I was 36.49±3.78 pg/ml, while in patients in group II it was 59.76±4.91 (p<0.01). ET-1 was also higher in patients with SD (230.47±59.55 pg/ml vs. 184.9±49.1 pg/ml, respectively, p<0.05). VEGF in the group without DM was 687.26±64.2 pg/ml, whereas in patients with DM this indicator was 998.24±77.55 pg/ml (p<0.001).

Next, an analysis of endothelial function in patients after a 6-month course of treatment with sulodexide was performed. As can be seen from Table 4, after a course of treatment with sulodexide, a significant improvement in cuff test indicators was noted in patients in both groups (p<0.05), but in patients without diabetes, the improvement in EF was more pronounced than in those with diabetes. In patients in group I, D1 increased from 0.49±0.01 cm to 0.54±0.02 cm (p<0.05), Vmin at 1 minute from 9.14±0.38 cm/s to 11.7±0.41 cm/s (p<0.05), EZVD increased from 7.76±1.7% to 10.48±2.15% (p<0.05), IR decreased from 0.77±0.01 to 0.7 ±0.013 (p<0.05), IR at 1 minute also decreased from 0.75±0.011 to 0.68±0.012 (p<0.05) (Table 4). All this indicates better vascular endothelial function and the ability of blood vessels to adequately vasodilate. In patients in group II, ESVD increased from 4.8 ± 1.29% to 6.95 ± 1.3% (p < 0.05), IR decreased from 0.8 ± 0.015 to 0.73 ± 0.014 (p < 0.05), IR at 1 minute also decreased from 0.77±0.013 to 0.70±0.013 (p<0.05) (Table 4). Thus, the indicators reflecting the improvement in EF during the cuff test are a decrease in IR, IR at 1 minute, and an increase in EDVD.

Table 4.

Dynamics of cuff test indicators in examined patients after 6 months of treatment with sulodexide

Index	CHD nonDM		CHD with DM	
	Before	After	Before	After
D0, sm	0,45±0,01	0,45±0,01	0,44±0,01	0,45±0,01
D1, sm	0,49±0,01	0,54±0,02*	0,46±0,01	0,5±0,01
Vmax, sm/sec	66,1±3,14	69,5±3,5	71,9±1,69	70,6±3,8
Vmin, sm/sec	7,41±0,25	7,7 ±0,27	8,58±0,51	8,3±0,47
RI, y.e.	0,77±0,01	0,7 ±0,013*	0,8±0,015	0,73±0,014*
Vmax 1 min, sm/sec	77,3±3,87	85,6±4,32	74,6±2,38	78,7±3,68
Vmin 1 min, sm/sec	9,14±0,38	11,7±0,41*	8,8±0,62	9,6±0,53
RI 1 min, y.e.	0,75±0,011	0,68±0,012*	0,77±0,013	0,70±0,013*
EDVD, %	7,76±1,7	10,48±2,15*	4,8±1,29	6,95±1,3*

Note: difference in indicators before and after treatment in patients in the same group: *- p<0.05

In addition to the cuff test, patients also underwent repeated laboratory blood tests for IL-6, ET-1, and VEGF concentrations. After a 6-month course of treatment with sulodexide, a significant improvement in IL-6 and ET-1 indicators was observed in patients in both groups, but VEGF decreased significantly only in patients with diabetes mellitus (Table 5). In patients in group I, IL-6 decreased from 36.49±3.78 pg/ml to 25.34±2.84 pg/ml (p<0.05), ET-1 decreased from 184.9±49.1 pg/ml to 48.69±4.05 pg/ml (p<0.001) (Table 5). In patients in group II, IL-6 decreased from 59.76±4.91 pg/ml to 33.84±3.08 pg/ml (p<0.05), ET-1 decreased from 230.47±59.55 pg/ml to 88.30±22.68

pg/ml (p<0.001), VEGF decreased from 998.24±77.55 pg/ml to 683.33±39.15 pg/ml (p<0.001)

Discussion of the results obtained.

The vascular endothelium plays a key role in maintaining vascular homeostasis [10]. The independent role of the vascular endothelium in regulating vascular tone was first reported in an article by R. Furchgott and J. Zawadzki in 1980. The main role in this was attributed to endothelial cells, which were characterised by the authors as «a cardiovascular endocrine organ that mediates communication between blood and tissues in critical situations» [11]. Subsequently, it was proven that the endothelium is an active organ, the dysfunction of which is mandatory in the pathogenesis of virtually all cardiovascular diseases, including atherosclerosis, hypertension, IHD, CHF, etc.

It has been established that the endothelium indirectly affects vascular tone through the release of vasodilatory and vasoconstrictive factors and modulates the contractile activity of smooth muscle cells [12]. Since endothelial dysfunction contributes to the development and progression of atherosclerosis, which ultimately leads to cardiovascular disease (CVD) [13], researchers are studying strategies for assessing endothelial dysfunction as an early biomarker of cardiovascular disease [14]. In 1992, Celermajer et al. [15] introduced the cuff test for non-invasive assessment of endothelial function using ultrasound. Currently, the cuff test has become a popular diagnostic method for ED due to its non-invasiveness, sensitivity [16], and correlation with coronary artery endothelial function [17].

Meta-analyses show that a 1% increase in ABI is associated with a 12-13% reduction in the likelihood of cardiovascular events, indicating that the cuff test may be a useful vascular biomarker for cardiovascular risk stratification [18]. Clinical studies have demonstrated a relatively close correlation between brachial artery endothelial function, as assessed by cuff testing, and coronary artery endothelial function, assessed by changes in epicardial coronary artery diameter in response to shear stress or intracoronary administration of acetylcholine for 5 minutes [19].

That is why we chose the cuff test as an examination to assess the condition of the endothelium. By applying this research method to patients, we proved a close correlation between this research method and laboratory indicators (IL-6, ET-1, VEGF) reflecting the condition of the endothelium. These laboratory parameters are recognised as markers for assessing the condition of the endothelium [20, 21]. In our study, patients with IHD showed a significant decrease in PVR compared to the control group, but the greatest decrease in PVR was observed in patients with diabetes mellitus. Impaired coronary artery endothelial function, manifested by the inability of blood vessels to dilate adequately when the myocardium's oxygen demand increases, contributes to the onset and progression of ischaemia. In patients with T2DM, it is necessary to assess the vasomotor function of the arterial endothelium to predict cardiovascular complications and diagnose ED at an early stage, which in turn will allow adequate therapy to be initiated and thus improve the quality of life of patients with IHD.

Recently, there has been increasing interest in studying the effect of drugs on the condition of the vascular endothelium. We chose sulodexide as a drug that has a positive effect on the endothelium. There are many studies on the use of sulodexide in patients with coronary artery disease [9]. A group of Turkish scientists has found that sulodexide exerts concentration-dependent inhibition of vasoconstriction, emphasising the critical role of intact endothelium and NO-mediated pathways in this process [22]. This highlights the role of sulodexide in the treatment of pathologies associated with endothelial dysfunction.

However, there are no specific data in the literature on such long-term use of sulodexide in patients with IHD, and there are also few studies comparing the effects of sulodexide on patients depending on the presence of diabetes mellitus. Therefore, our goal was to study this issue. As a result of our study, we examined the efficacy and, most importantly, the safety of long-term sulodexide use in patients with IHD. The results of our study proved the positive effect of sulodexide on the functional state of the endothelium in the form of improved cuff test indicators and reduced laboratory indicators reflecting the severity of ED.

Conclusions. Having analysed all of the above, we can confidently recommend sulodexide at a dose of 500 LE/day for a period of 6 months to patients with IHD, both with and without diabetes mellitus, to improve the functional state of the endothelium. Sulodexide has proven its positive effect on the condition of the endothelium in patients with IHD according to laboratory and instrumental studies. An examination such as a cuff test can be easily used to assess the condition of the endothelium and monitor the effectiveness of treatment, as this diagnostic method is affordable, minimally invasive and informative.

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ACUTE PHLEGMONOUS GASTRITIS – CASE REPORT

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Abstract
Starting from a surgically resolved case, the paper provides an updated analysis of the mechanisms, clinical features, and diagnostic considerations for acute phlegmonous gastritis, along with possible therapeutic solutions.

Keywords: phlegmonous gastritis, surgical treatment

1. INTRODUCTION

Acute phlegmonous gastritis (AGF) is a rare condition, characterized mainly by severe bacterial invasion of the gastric wall. The clinical manifestations of AGF are nonspecific: abdominal pain, nausea, vomiting, fever and signs of infection. Early diagnosis is difficult, given that the disease develops rapidly, progressing to necrosis of the gastric wall and peritonitis. Therefore, diagnosis is delayed or ignored, and AGF has a high mortality rate. If before the era of antibiotics, the mortality rate reached 92%, with antibiotic therapy, the mortality rate decreased to 48%. However, immediate surgical intervention remains necessary to improve the prognosis, when antibiotic treatment is ineffective. The paper presents a case of AGF, diagnosed and treated in our department.

2. CASE REPORT

A 56-year-old woman admission, presenting with epigastric pain, fever (39-40ºC) and vomiting, for 4 days, with worsening in the last 24 hours. From the anamnesis, moderate constant ethanol consumption was noted, a so-called old gastric ulcer, without regular treatment and an acute respiratory infection (about 2 weeks ago), treated with oral and symptomatic anti-inflammatories, but which had not completely resolved. On the recommendation of the family doctor, the patient administered Zinnat (cefuroxime), but the situation did not improve, and even worsened, in the last hours, which is why she was sent to the hospital.

Upon admission, she presented with fever 39.2°C, tachycardia 126/min, with blood pressure within normal limits 130/80 mmHg. Physical examination revealed dyspnea and muscular defense, predominantly in the upper abdominal area. Laboratory tests: leukocytes 6500/mm3, with neutrophils 88%. Contrast-enhanced computed tomography (CT) revealed that the entire gastric wall was thickened, due to edema, without signs of perforation.

Antibiotic – Tienam (imipenem/cilastatin), antacids, analgesics and rehydration were administered, obtaining a slight improvement, after which the abdominal pain intensified, vomiting with a purulent tinge was repeated. Median supraumbilical laparotomy revealed: cloudy-purulent perigastric fluid; the stomach wall presented necrotic - nigrescent areas, at the body and antrum level. A 4/5 gastrectomy was decided and performed, followed by reconstruction by gastrojejunal anastomosis on a Y-loop, and double peritoneal drainage – subhepatic and of the Douglas pouch. The peritoneal fluid sample was sent to the laboratory for culture and antibiogram. Under intensive treatment, continuing the initiated antibiotic therapy, the postoperative evolution was favorable, with discharge cured after 10 days.

3. DISCUSSION

GAF was originally described by Cruveilhier in the early 18th century and, in the last 50 years, an average of 1 case/year has occurred. The disease can affect all age groups, but is more common in adults over 50 years of age, with a male-female ratio of 2:1. Although rare, especially after the use of antibiotics, GAF becomes urgent and develops rapidly once it appears. With the high mortality of this disease, early recognition and immediate action are crucial. With <500 cases reported in the literature, it requires the attention of medical personnel.

Even now, the etiopathogenesis of GAF is not completely elucidated, the cause being considered to be bacterial suppuration, which invades the stomach. Hemolytic streptococcus is found in about 70% of cases, followed by Staphylococcus aureus, Pneumococcus and Enterococcus. Bacterial invasion of the gastric wall can be facilitated by a gastric ulcer or chronic gastritis. Pathogenic bacteria of the pharynx can directly affect the damaged mucosa, but also a respiratory tract infection or other infection, with pathogenic bacteria, that penetrate the gastric wall via the blood or lymphatic route. Alcohol consumption, malnutrition and advanced age are favorable conditions. In the presented case, the patient had as a predisposing factor long-term alcohol consumption, probably a pre-existing gastritis and had not fully recovered from the recent respiratory tract infection. Considering that hemolytic streptococcus was cultured from peritoneal fluid collected intraoperatively, we assumed that the GFA was caused by this pathogen, common for respiratory infections.

We can imagine that the pathophysiological process begins with the bacterial invasion of the submucosa, which then propagate and diffuse into the mucosa, muscularis and serosa. Two types of microbial invasion of the stomach are described: diffuse and localized, depending on the interval of the lesion.

- the diffuse type is more frequent clinically and presents a dark red gastric wall, with diffuse thickening; when the stomach wall is squeezed, pus is discharged. This type can also cause the extension of the lesion, with perforation of the gastric wall, in severe circumstances.

- the localized type presents hyperemia and erosion of the gastric mucosa, ulceration, necrosis or bleeding.

The localized type is associated with a lower mortality rate than the diffuse type (10%:55%). In our patient, the stomach wall was obviously thickened, and necrosis was found on the entire circumference of the gastric body and antrum; perigastrically there was a tendency for an abscess to form. Therefore, this case belonged to the diffuse type.

Early diagnosis of AGF is difficult, due to the nonspecific nature of its clinical manifestations, including acute abdomen syndrome, sudden onset of abdominal pain, high fever and chills, nausea and vomiting. Thus, differential diagnosis with other conditions belonging to the acute abdomen (e.g. peritonitis due to perforation of a hollow organ, acute cholecystitis, acute pancreatitis) is necessary. With the development of the disease, fever may increase, signs of peritoneal irritation become evident and vomiting may become purulent. Abdominal CT usually finds the characteristic features of GAF: thickening of the gastric wall, areas of low intensity within the gastric wall (abscess) and gas accumulation. The patient's clinical presentation included abdominal pain, epigastric peritonitis and characteristic CT. In the presented case, purulent vomiting and CT examination were defining for the positive diagnosis of GAF, distinguishing it from other entities of the acute abdomen.

Acute GAF has a high mortality rate, and the key to successful treatment is early diagnosis and treatment. Before the advent of antibiotics, the mortality rate was 83% to 92%, and the mortality rate has decreased to 48% even after antibiotics became available. In addition, nutritional support and rehydration are very important for therapeutic success. However, if conservative treatment is ineffective, surgery should be performed immediately to avoid worsening the disease. The patient's condition worsened after conservative treatment. Therefore, emergency surgery was performed, with postoperative supportive treatment. The patient eventually recovered.

4. CONCLUSIONS

GAF does not have a specific clinical picture, evolving as an acute abdomen

Abdominal CT is useful for both early diagnosis and detection of complications.

Once APG is detected, antibiotic treatment is important and mandatory, but if this treatment fails, surgery should be performed immediately to improve the prognosis.

Currently, given the use of antibiotics, the incidence rate of GAF is very low. However, once the disease occurs, it progresses rapidly and has an extremely high mortality rate. Therefore, it requires serious attention from clinicians.

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RESULTS OF COMPLEX TREATMENT OF LOCANY-ADVANCED CERVICAL CANCER WITH USING OF RADIOIOMODIFIERS

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РЕЗУЛЬТАТЫ КОМПЛЕКСНОГО ЛЕЧЕНИЯ БОЛЬНЫХ МЕСТНО-РАСПРОСТРАНЕННЫМ РАКОМ ШЕЙКИ МАТКИ С ВКЛЮЧЕНИЕМ В СХЕМУ ЛЕЧЕНИЯ РАДИОМОДИФИКАТОРОВ

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Abstract

This study demonstrates the results of the complex treatment of 53 patients with squamous cell uterine cervix cancer stage IIB. In the preoperative period all the patients received a combination of the combined radiotherapy (distant + intracavitary) and intravenous administration of the cysplatin with the subsequent Wertheim surgery. During the preoperative chemoradiotherapy 31 of the 53 patients) were treated with transrectal insufflation of the ozone-oxygen mixture as a radiomodificator. Besides, the original technique, and hardware and software implementation of the pulsoximetric assessment of the tumor oxygenation were used. In the postoperated period the tumor therapeutic pathmorphism, quantity of side effects of the chemoradiotherapy and postoperative complications were comparatively analyzed in the both groups. The undoubted benefits of the usage of the ozone-oxygen mixture in the complex therapy of patients with squamous cell cervix cancer were proved.

Аннотация

Представлены результаты комплексного лечения 53 больных плоскоклеточным раком шейки матки IIb стадии. Всем пациенткам в предоперационном периоде использована комбинация сочетанной лучевой терапии (дистанционная + внутриполостная) и внутривенного введения цисплатина с последующей операцией Вертгейма. На этапе предоперационной химиолучевой терапии 31 больной из 53 выполнялась трансректальная инсуфляция озонокислородной смеси в качестве радимодификатора. При этом использована оригинальная методика и аппаратно-программная реализация пуль- соксиметрической оценки насыщения опухоли кислородом. В послеоперационном периоде произведен сравнительный анализ лечебного патоморфоза опухоли, количества побочных эффектов химиолучевой терапии и послеоперационных осложнений в обеих группах больных. Доказаны несомненные преимущества комплексной терапии больных плоскоклеточным раком шейки матки в условиях радиомодификации озонокислородной смеси.

Keywords: squamous cell cervical cancer, chemoradiotherapy, radiomodifications, ozone, therapeutic pathomorphism, complications.

Ключевые слова: плоскоклеточный рак шейки матки, химиолучевая терапия, радиомодификация, озон, лечебный пато- морфоз, осложнения.

Введение

Рак шейки матки (РШМ) на сегодняшний день остается одним из наиболее распространенных злокачественных новообразований (ЗНО). По показателям заболеваемости РШМ занимает 7-е место и 3-е место среди ЗНО у женщин, конкурируя с такими опухолевыми заболеваниями, как рак молочной железы и рак толстой кишки. По данным литературы, в мире ежегодно выявляется более 500 тыс. новых случаев РШМ и регистрируется около 300 тыс. умерших от этого заболевания [1].

Прогноз заболевания в значительной мере определяется распространенностью опухолевого

процесса. Для больных РШМ I стадии показатель 5-летней выживаемости составляет 78—99% и только 43—68% больных II—III стадии переживают 5-летний срок. К сожалению, у значительной части пациенток опухоль шейки матки диагностируется уже на поздних стадиях. Так, в 2011 г. в Российской Федерации РШМ I—II стадии выявлялся в 62,0% случаев, а III стадии — в 27,3%. В Республике Татарстан — 72,5 и 16,5% соответственно [2].

Известно, что лучевая терапия (ЛТ) является основным методом лечения больных РШМ. Большинство пациенток с РШМ подвергаются ЛТ, причем у 75% она являлась самостоятельным, а порой и единственным методом лечения [3, 4, 5]. Приведенные результаты за последние 25 лет свидетельствовали о том, что ЛТ является не только эффективным, но и перспективным методом лечения РШМ. Однако 30—40% больных умерли в ближайшие годы после завершения ЛТ в большинстве случаев от прогрессирования основного заболевания. В первые годы после лечения в зоне облучения рецидивы возникали у 10—40% пациенток, а у 35% больных обнаруживались отдаленные метастазы [3, 6]. Поэтому сама ситуация продиктовала необходимость смены традиционных подходов лучевого лечения РШМ.

Одним из перспективных направлений повышения эффективности ЛТ стало использование способов и средств, которые позволили бы расширить радио- терапевтический потенциал с помощью радиомодифицирующих агентов, т.е. избирательно усилить повреждение опухоли и одновременно снизить радиопоражаемость окружающих здоровых тканей [7, 8].

В качестве радиомодифицирующих агентов (РА) в клинической онкогинекологии активно использовались электроноакцепторные соединения (метронидазол), ингибиторы постлучевой репарации ДНК (8-хлоркофеин, 8-бромкофеин), гипербарическая оксигенация, искусственная гипергликемия, локальная гипертермия и химиотерапия [9, 10, 11, 12, 13, 14, 15, 16, 17, 18]. Применение радиомодификаторов позволило увеличить безрецидивный период у больных РШМ, продолжительность их жизни и снизить количество постлучевых осложнений [13, 14, 19, 20].

Однако тяжелые побочные эффекты радиомодификаторов (электроноакцепторные соединения, химиотерапевтические препараты), техническая сложность проведения радиомодификации и невозможность определения кислородного статуса опухоли в процессе вдыхания кислорода (гипербарическая оксигенация), топографо-анатомические ограничения и небезопасность использования самого метода (локальная гипертермия, искусственная гипергликемия) лимитировало применение РА в комплексной терапии местно-распространенного РШМ [7, 8, 21, 22].

Таким образом, становится очевидным факт, что до настоящего времени отсутствовал оптимальный радиомодификатор в комплексном лечении местнораспространенного РШМ, отвечающий двум основным требованиям: высокая эффективность и безопасность его использования.

Целью исследования является улучшение результатов комплексного лечения местно-распространенного плоскоклеточного рака шейки матки IIb стадии с использованием различных радиомодифицирующих агентов.

Материал и методы

Исследование проведено на базе ГАУЗ «Республиканский клинический онкологический диспансер Министерства здравоохранения Республики Татарстан» за период с 2008 по 2011 г. В исследовании участвовали 53 пациентки с местно-распространенным плоскоклеточным РШМ IIb стадии, проходивших лечение в отделениях радиологии №2 и онкологии №7. Возраст больных колебался от 24 лет до 63 лет (в среднем 42,2 года). Согласно Международной клинической классификации РШМ FIGO (2002 г.) в исследование были включены женщины со IIb стадией ($T_{2b}N_0M_0$), при которой опухоль прорастала в шейку матки с инвазией параметрия, но без распространения на близлежащие лимфатические узлы или отдаленные органы.

Основную группу составили 31 пациентка. Контрольную группу составили 22 пациентки. Сравниваемые группы больных по возрастному критерию репрезентативны. Различия статистически незначимые (p>0,05).

На первом предоперационном этапе лечения всем 53 пациенткам проводилась химиолучевая терапия (ХЛТ) по схеме, принятой с 1997 г. в НИИ онкологии им. Н.Н.Петрова [8]. Выполнялась дистанционная ЛТ на очаг и зоны регионарного метастазирования (подвздошные и параметральные лимфатические узлы) на линейных ускорителях SL-75, SL-20 в разовой очаговой дозе (РОД) 2 Гр до суммарной очаговой дозы (СОД) 30 Гр на точки А и В, комбинируя с внутриполостной ЛТ Co^{60} на аппарате АГАТ-В в РОД 10 Гр до СОД 20 Гр. Кроме того, еженедельно в течение трех недель внутривенно капельно вводился цисплатин в суммарной дозе 120 мг (по 40 мг в нед).

Все больные были разделены на две группы: 31 пациентке (58,5%) (основная группа) из 53 проводили трансректальную инсуфляцию озонокислородной смеси (ОКС) в качестве радиомодификатора перед каждым сеансом облучения. Для этой цели использовали аппарат «Медозон-ВМ» (Н.Новгород) с подачей озона на выходе 10 ц/ml на 1,5 л (суммарная доза 15 мг). Применяя данный метод лечения, мы отталкивались от той концепции, что оксигенация опухоли повышает ее чувствительность к воздействию ионизирующей радиации, тем самым усиливая радиомодифицирующий эффект ЛТ. При этом была использована оригинальная методика и аппаратнопрограммная реализация пульсоксиметрической оценки насыщения опухоли кислородом (приоритетная справка на изобретение № 201 1 1 39690 от 29.09.11 г.). В качестве регистрирующего устройства, определяющего кислородный статус опухоли, мы применили фотоплетизмографические датчики пульсоксиметра, размещенные

на концах браншей зажима. Помещая между браншами зажима опухолевую ткань, определяли, таким образом, сатурацию кислорода в ней [положительное решение о выдаче патента РФ по заявке за № 2012123879/14 (036540) от 10.08.12 г.]. В качестве интерпретирующего устройства был использован электронный блок монитора прикроватного реаниматолога МПР5-02.

Показатели сатурации кислорода до введения в прямую кишку ОКС колебались от 76 до 84% (в среднем 80%), что прямо свидетельствовало о гипоксии опухоли. После инсуфляции ОКС показатели оксигенации опухоли достигали своего максимума, т.е. 99% в среднем к 20-й мин (интервал от 16 до 28 мин), после чего сразу начинали сеанс ЛТ.

Остальным 22 (41,5%) пациенткам (контрольная группа) мы провели предоперационную ХЛТ по вышеописанной схеме без применения ОКС. Таким образом, мы на практике реализовали принцип системной полирадиомодификации (ОКС+химиотерапия) в комплексном лечении больных местно-распространенным РШМ IIb стадии.

На втором этапе, через три недели после ХЛТ, всем 53 (100%) пациенткам выполнили радикальную гистерэктомию с двусторонней подвздошной лимфаденэктомией по методу Вертгейма—Мейгса.

Для определения степени лечебного патоморфоза, после проведенного лечения использовался метод качественной морфологический оценки, предложенный Г.А. Лавниковой и З.В. Гольберт (1979). Согласно этой схеме к IV степени повреждения относят полное (100% регресс) исчезновение элементов опухоли. При III степени (регресс более 50%) определяются остатки опухоли в виде разрозненных групп клеток с резкими дистрофическими изменениями. Ко II степени (регресс менее 50%) относят опухоли, в которых основная масса паренхимы сохранена при наличии выраженных дистрофических изменениях в клетках. При I степени патоморфоза (отсутствие регресса) структура опухоли полностью сохранена, имеется лишь подавление митозов и не свойственный данной опухоли полиморфизм и дистрофия клеток.

Результаты и их обсуждение

Для оценки переносимости предоперационной ХЛТ проведен анализ частоты осложнений в ходе лечения по критериям NCI—CTC. Все осложнения носили транзиторный характер и хорошо поддавались симптоматическому лечению. Однако была отмечена тенденция к их значительному снижению в экспериментальной группе больных. Как осложнения ЛТ цистит был констатирован у 1 (3%) пациентки основной группы и у 2 (9%) контрольной; ректиты — у 5 (16%) больных основной и у 4 (18%) контрольной группы. Из гематологических осложнений, таких как осложнения химиотерапии, чаще всего отмечалась лейкопения (I—II степени) у 7 (22%) больных основной и у 17 (72,2%) контрольной группы. И наконец, гриппоподобный синдром наблюдался у 1 (3%) пациентки основной и у 2 (9%) контрольной группы. Проявлений III и IV степени токсичности не было *(*таблица 1*)*.

Так как число наблюдений мало (n<30), для оценки существенности различий применяли сопоставление доверительных интервалов показателей (интервалы, в границах которых с заданной вероятностью находятся истинные показатели), определяемых на основе параметра распределения Пуассона. Поскольку доверительные интервалы оцениваемых показателей при p=95% накладываются, можно сделать вывод о несущественности выявленных различий. Таким образом, уменьшение частоты осложнений ЛТ можно считать статистически незначимым.

Таблица 1

Анализ частоты осложнений лучевой терапии

Осложнение	Частота осложнений		t	p	k	Доверительный интервал
	Основная группа (n=31)	Контрольная группа (n=22)				
Цистит	1	2	0,222	0,645	2	0,000 — 0,328
Ректит	5	4	0,316	0,789	2	0,052 — 0,465
Лейкопения (I—II степени)	7	17	0,041	0,971	2	0,090 — 1,237
Гриппоподобный синдром	1	2	0,222	0,645	2	0,000 — 0,328

При ректальной инсуфляции ОКС осложнений не было. Лишь у 8 (25,8%) пациенток наблюдались незначительные болевые ощущения и явления метеоризма в процессе инсуфляции, которые купировались самостоятельно.

Предоперационная ХЛТ не оказала никакого отрицательного влияния на ход оперативного вмешательства. Как интраоперационных, так и послеоперационных осложнений не наблюдалось.

Лечебный патоморфоз опухоли IV степени установлен у 14 (44,8%) больных основной и у 6 (27,2%) контрольной группы; III степени — у 10 (32,2%) основной и у 9 (41%) контрольной группы; II степени — у 6 (20%) основной и у 6 (27,3%) контрольной группы; I степени — у 1 (3%) основной и у 1 (4,5%) контрольной группы соответственно. При гистологическом исследовании удаленного препарата в послеоперационном периоде метастазы в подвздошные лимфатические узлы обнаружены у 7 (22,6%) больных основной и у 3 (13,6%) контрольной группы, что явилось основанием для проведения ЛТ в послеоперационном периоде.

В послеоперационном периоде, учитывая наличие факторов риска (метастазы в лимфатических узлах, глубокая инвазия опухоли, низкая степень дифференцирования, I—III степень лечебного

патоморфоза, наличие раковых эмболов в лимфатических сосудах), проводилась послеоперационная дистанционная ЛТ (ДЛТ) в РОД 2 Гр до СОД 10—20 Гр. В основной группе послеоперационная ДЛТ была проведена 17 (55,2%) пациенткам, а в контрольной — 16 (72,8%) больным.

За период наблюдения (2008—2011 гг.) в обеих группах погибло по одной пациентке к окончанию первого года с момента установления диагноза от прогрессирования основного заболевания, что составило 3,2% в основной группе и 4,6% в контрольной группе соответственно.

Выводы

1. Предложенная нами схема предоперационной ХЛТ местно-распространенного РШМ IIb стадии в условиях радиомодификации ОКС характеризуется высокими показателями лечебного патоморфоза IV степени опухолевой ткани, достигающего 44,8%.

2. Применение ректальной инсуфляции ОКС позволило снизить абсолютное количество постлучевых и химиотерапевтических осложнений у больных РШМ (разница статистически не существенна).

3. Для достоверной оценки эффективности предложенного метода радиомодификации необходимо большее количество клинических примеров и сроков наблюдения.

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PEDAGOGICAL SCIENCES

ORGANIZATIONAL METHODOLOGY OF A CHEMISTRY EXPERIMENT RECOMMENDED FOR USE IN TEACHING TOPICS RELATED TO "CLASSIFICATION OF CHEMICAL REACTIONS" IN SECONDARY SCHOOLS

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ÜMUMTƏHSİL MƏKTƏBLƏRİNDƏ "KİMYƏVİ REAKSİYALARIN TƏSNİFATI"-NA AİD MÖVZULARIN TƏDRİSİNDƏ İSTİFADƏSİ TÖVSİYƏ OLUNAN KİMYA EKSPERİMENTİNİN TƏŞKİLİ METODOLOGİYASI

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Abstract

It should be noted that one of the most difficult points for students in teaching chemistry in secondary schools is the experimental study of the subject. Every chemistry teacher should work in the process of teaching the subjects so that students do not approach chemistry as an introduction to the basics of a certain science. In the process of teaching chemistry, the methodology for organizing experiments based on laboratory and practical exercises in the teaching process should be correctly determined in order to develop the observational skills, critical thinking, and the ability to draw conclusions from the knowledge they have acquired in the subjects taught in the process of teaching chemistry.

Xülasə

Qeyd etməliyik ki, ümumtəhsil məktəblərində kimya fənninin tədrisində şagirdlərin ən çox çətinlik çəkdiyi məqamlardan biri də mövzunun eksperimental tədqiqidir. Hər bir kimya müəllimi mövzuların tədrisi prosesində çalışmalıdır ki, şagirdlər kimya fənninə təkcə müəyyən elmin əsasları ilə tanışlıq kimi yanaşmasınlar. Kimyanın tədrisi prosesində öyrədilən mövzuların şagirdlərdə mövzu ilə bağlı müşahidəçilik qabiliyyətlərinin, tənqidi təfəkkürlərinin, əldə etdikləri biliklərdən nəticə çıxarmaq bacarıqlarının inkişaf etdirilməsi istiqamətində dərs prosesində laboratoriya və praktiki məşğələlərə əsaslanan eksperimentlərin təşkili metodikası düzgün müəyyən olunmalıdır.

Keywords: Practical exercise, combination reactions, decomposition reactions, substitution and exchange reactions.

Açar sözlər: Praktik məşğələ, birləşmə reaksiyaları, parçalanma reaksiyaları, əvəzetmə və mübadilə reaksiyları.

Ümumtəhsil məktəblərində VII və VIII sinif kimya kursunda "Kimyəvi reaksiyaların təsnifatına" aid mövzunun tədrisində bölmə sonunda praktiki məşğələlərin təşkili zamanı istifadəsi tövsiyə olunan laboratoriya təcrübələri:

Birləşmə reaksiyaları

FƏALİYYƏT 1.
Təchizat: *zink tozu, yod kristalı, distillə suyu, saat şüşəsi, pipet*

Təlimat.
1. Saat şüşəsi üzərinə 1q sink tozu və 2q yod kristalı əlavə edib şüşə çubuqla qarışdırın.
2. Sink tozu və yod kristalından ibarət qarışığın üzərinə pipet vasitəsi ilə 1-2 damcı distillə suyu əlavə edin.

Müşahidələrinizi qeyd edin.
Bənövşəyi rəngli buxarın əmələ gəlmə səbəbini izah edin.

Bölmə ilə bağlı praktiki məşğələlərin təşkili zamanı bu təcrübənin yerinə yetirilməsində əsas məqsədimiz şagirdlərin zehni fəaliyyəti zamanı kimyəvi kinetikaya aid mövzular arasında düzgün əlaqənin qurulmasını təmin etməkdir. Belə ki, bu təcrübənin yerinə yetirilməsi zamanı hər bir qrup üzvü bir neçə mövzunun dərk edilib, əlaqələndirilməsi istiqamətində zehni fəaliyyətdə olur. Bu təcrübədə şagird mövzunu təkrarlamış olur:

1. İki və ya daha artıq bəsit və ya mürəkkbə maddədən bir yeni maddənin əmələ gəlməsi ilə gedən reaksiyalar birləşmə reaksiyalarıdır.
2. Əksər birləşmə reaksiyaları yeni rabitələrin əmələ gəlməsi səbəbindən ekzotermik reaksiyalardır.
3. Reaksiyanın gedişi prosesində yod kristallarının sublimasiya edərək bənövşəyi rəngli buxar əmələ gətirməsinə səbəb məhz ekzotermik reaksiya zamanı ayrılan istilikdir.

$$Zn + J_2 \xrightarrow{H_2O} ZnJ_2 + Q$$

Birləşmə reaksiyaları

FƏALİYYƏT 2.
Təchizat: *alüminium tozu, kükürd tozu, çini puta, azbest toru, şüşə çubuq, distillə suyu*

Təlimat.
1. İlk öncə 2q alüminium tozu ilə 1q kükürd tozunu çini putaya tökün.
2. İçərində qarışıq olan çini putanı şativə bərkidilmiş üzərində azbest toru olan dəmir halqaya yerləşdiririk.
3. Halqanın aşağısındakı spirt lampasını yandırıb şüşə çubuğu isidərək alüminium və kükürd tozunu qarışığını qarışdırırıq.
4. Sonda qarışığa pipet vasitəsi ilə 2-3 damcı distillə suyu əlavə edin

Müşahidələrinizi qeyd edin.
* "Çılçırağ"-ı xatırladan qığılcımın əmələ gəlməsi səbəbini izah edin.
* Təcrübənin sonunda spesifik iyin əmələ gəlmə səbəbini izah edin.

Bu təcrübənin yerinə yetirilməsində əsas məqsəd şagirdlərin mövzu ilə bağlı prosedural biliklərini

möhkəmləndirməklə yanaşı, həmçinin onlarda fəndaxili inteqrasiyanın düzgün təşkil edilməsini formalaşdırmaqdır.

1. Beləki, alüminium və kükürd müəyyən temperatur nəticəsində birləşmə reaksiyasına daxil olur.

2. Reaksiya istiliyin ayrılması ilə gedən ekzotermik reaksiyadır.

3. Alınan ZnS birləşməsinin üzərinə distillə suyunu əlavə etdikdə zink-sulfidin hidroliz etməsi nəticəsində əmələ gələn xoşagəlməz spesifik "lax yumurta" iyli qaz isə hidrogen-sulfid qazıdır.

Parçalanma reaksiyaları

FƏALİYYƏT 3

Təchizat: ammonium-bixromat, maqnezium lenti, çini kasa, kibrit

Təlimat.

1. Çini kasaya narıncı rəngli ammonium-bixromat töküb kiçik təpəcik şəklində yığın və ortasına maqnezium lentini qoyun.
2. Maqnezium lentini kibritlə yandırın.

Parçalanma reaksiyaları

FƏALİYYƏT 3.

Təchizat: *ammonium-bixromat, maqnezium lenti, çini kasa, kibrit*

Təlimat.

1. Çini kasaya narıncı rəngli ammonium-bixromat töküb kiçik təpəcik şəklində yığın və ortasına maqnezium lentini qoyun.
2. Maqnezium lentinə kibritlə yandırın.

Müşahidələrinizi qeyd edin.

1. Narıncı rəngli kristallik ammonium-bixromat temperaturun təsirindən ani parçalanaraq yaşıl rəngli üçvalentli xrom ionuna çevrilir (xromun bütün III valentli birləşmələri yaşıl rənglidir).

2. Parçalanma reaksiyası olsa da, istisna reaksiyadır ki, ekzotermikdir, yəni istiliyin ayrılması hesabına baş verir.

3. Bu reaksiyanın "süni vulkan" reaksiyası adlandırılmasına səbəb əmələ gələn azot qazının yaratdığı təzyiq hesabına xrom (III) oksidin küllərinin havaya qalxaraq vulkanı xatırlatmasıdır.

$$\underset{\text{narıncı}}{(NH_4)_2Cr_2O_7} \xrightarrow{t} N_2\uparrow + \underset{\text{yaşıl}}{Cr_2O_3} + 4H_2O$$

Parçalanma reaksiyaları

FƏALİYYƏT 4.

Təchizat: *Əsasi mis (II) karbonat, əhən suyu, 2 sınaq şüşəsi, içərisindən qazaparan boru keçirilmiş tıxac, ştativ, spirt lampası*

Təlimat.

1. Firuzəyi-yaşıl rəngli malaxiti quru sına şüəsinə tökün və ağzını içərisindən qazaparan boru keçirilmiş tıxacla bağlayın.
2. İçərisində malaxit olan sınaq şüşəsini ştativin pəncəsinə bərkidin və sınaq şüşəsinin altına spirt lampasını yerləşdirin.
3. Qazaparan borunun digər ucunu isə içərisində əhən suyu olan digər sınaq şüşəsinə daxil edib, spirt lampasını yandırın.

Müşahidələrinizi qeyd edin.

Bu təcrübəni təkcə kimyəvi reaksiyaların təsnifatına aid mövzunun tədrisində deyil, həmçinin karbon(IV)oksid, IIA və IB qrup elementlərinə aid mövzuların tədrisində də bu mövzuya inteqrasiya yaratmaq üçün istifadəsi tövsiyə edilir.

1. Firuzəyi-yaşıl rəngli əsasi mis (II) karbonat qara rəngli mis(II)oksidə çevrilməyə başlayır.
2. Reaksiya nəticəsində su ayrıldığı üçün sınaq şüşəsinin divarlarında su damcıları müşahidə olunur.
3. Həmçinin, karbon(IV)oksid əmələ gələrək əhəng suyunu bulandırmağa başlayır.
4. Bir müddət sonra əhəng suyunun yəni kalsium hidroksidin karbon(IV)oksidlə reaksiyasından bulantının əmələ gəlməsi ilə yaranan kalsium-karbonat karbon qazının artığında həll olaraq kalsium-hidrokarbonatın əmələ gəlməsi hesabına yenidən şəffaflaşır.

a) $(CuOH)_2CO_3 \xrightarrow{t} 2CuO + CO_2\uparrow + H_2O$
firuzəyi-yaşıl qara
b) $CO_2\uparrow + Ca(OH)_2 \rightarrow CaCO_3\downarrow + H_2O$
ağ
c) $CaCO_3\downarrow + H_2O + CO_2\uparrow \rightarrow Ca(HCO_3)_2$
ağ

Əvəzetmə və neytrallaşma reaksiyaları

FƏALİYYƏT 5.
Təchizat: *Natrium metalı, xlorid turşusu (HCl), fenolftalein məhlulu, pipet, sınaq şüəsi, kibrit.*

Təlimat.
1. Kerosinin içərisində saxlanılmış natrium metalından pinset vasirəsilə götürüb süzgəc kağızı üzərində buğdanın yarısı boyda kəsib, süzgəc kağızı ilə qurudun.
2. Sınaq şüşəsinə yarısına kimi su töküb, üzərinə pipet vasitəsi ilə 2-3 damcı fenolftalein məhlulu əlavə edib qarışdırın.
3. Kerosindən təmizlənmiş natrium metalını sınaq şüşəsinin içərisinə atın.
4. Daha sonra sınaq şüşəsinin ağzına yanar çöp yaxınlaşdırın.
5. Məhlul moruğu rəngə boyandıqdan sonra həmin məhlulun üzərinə pipet vasitəsi ilə 3-4 damcı HCl əlavə edin.

Müşahidələrinizi qeyd edin.

Bu təcrübənin aparılmasında məqsəd əvəzetmə və mübadilə reaksiyalarının hidrogen mövzusu, eləcə də, əsaslar mövzusu ilə inteqrasiyasını təmin etməkdir.

1. Bəsit maddə atomlarının mürəkkəb maddənin atomlarından birini əvəz etməsi ilə gedən reaksiyalara əvəzetmə reaksiyaları deyilir.
2. Natriumun su ilə qarşılıqlı təsirindən NaOH (qələvi) əmələ gəlir.
3. $2Na + 2H_2O \rightarrow 2NaOH + H_2\uparrow$
4. Əmələ gələn qələvi indikator olan fenolftalein məhlulu ilə təyin edildi. Qələvilərin təsirindən fenolftalein moruğu, lakmus isə göy rəngə boyanır.
5. Natriumun su ilə reaksiyasından həmçinin hidrogen qazı ayrılır ki, reaksiyanın gedişi prosesində natrium metalını suyun üzərində sürətli hərəkət etdirən də həmin ayrılan hidrogen qazıdır.
6. Hidrogen qazının ayrılması isə yanar çöplə təyin edilir ki, bu zaman yanar çöp hidrogen qazının təsirindən "pax" səsi ilə sönür.
7. Turşu və əsas arasında baş verən mübadilə reaksiyalarına neytrallaşma reaksiyaları deyilir.
8. Tərkibində NaOH və fenolftaleindən ibarət moruğu rəngli məhlul üzərinə xlorid turşusu əlavə etdikdə məhlul rənsizləşər. Bu zaman məhlul turşu və əsas arasında baş verən neytrallaşma reaksiyası hesabına rəngsizləşir.
9. $NaOH + HCl \rightarrow NaCl + H_2O$

Mübadilə və parçalanma reaksiyaları

FƏALİYYƏT 6.

Təchizatlar: *mis (II) sulfat məhlulu, natrium-hidroksid məhlulu, 2 ədəd sınaq şüşəsi, pipet, tutqac, spirt lampası*

Təlimat.

1. Hər iki sınaq şüşəsində ayrı-ayrılıqda 5-6 damcı mavi rəngli mis(II)sulfat məhlulu üzərinə çöküntü alınana qədər natrium-hidroksid məhlulu əlavə edin.
2. Çöküntü alınan sınaq şüşələrindən birinin içərisindəki çöküntünü məhluldan süzgəc kağızı vasitəsi ilə ayırın.
3. Çöküntü alınan digər sınaq şüşəsini isə tutqac vasitəsi ilə spirt lampası alovunda qızdırın

Müşahidələrinizi qeyd edin.

Bu təcrübənin yerinə yetirilməsində əsas məqsəd şagirdlərin həm mübadilə və parçalanma reaksiyalarına aid təcrübələr arasında asılılığı qurmalarına, həm də qarışıqların ayrılması mövzusuna fəndaxili inteqrasiya yaratmaq qabiliyyətlərinin formalaşdırılmasına nail olmaqdır.

1. İki mürəkkəb maddə arasında baş verib iki yeni mürəkkəb maddənin əmələ gəlməsi ilə gedən reaksiyalara mübadilə və ya dəyişmə reaksiyaları deyilir.

2. Mis(II)sulfat və natrium-hidroksid arasındakı mübadilə reaksiyası nəticəsində göy rəngli mis(II)hidroksid çöküntüsü əldə edildi.

$CuSO_4 + 2NaOH \rightarrow Cu(OH)_2\downarrow + Na_2SO_4$

mavi göy

3. Tərkibində göy rəngli mis(II)hidroksid çöküntüsü olan məhlulu qızdırdıqda baş verən parçalanma reaksiyası nəticəsində çöküntünün parçalanaraq mis(II)oksid əmələ gəlməsi nəticəsində məhlul qara rəngə boyandı.

4. $Cu(OH)_2\downarrow \xrightarrow{t} CuO + H_2O$

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ENHANCING MILITARY ENGLISH LEARNING THROUGH STRATEGIC INSTRUCTION AND AUTHENTIC ASSESSMENT

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Abstract

The article focuses on Military English teaching, which prepares military personnel for communication in multinational settings like peacekeeping missions and joint exercises. Unlike general English, it emphasizes terminology related to defense, logistics, commands, and emergency procedures, and includes training in listening, speaking under pressure, and interpreting technical documents. It highlights the use of **Content and Language Integrated Learning (CLIL)** and **Task-based Language Teaching (TBLT)**. CLIL integrates language and content tasks but faces challenges in teacher collaboration. TBLT enhances motivation and learning outcomes through task-based activities, though its effectiveness varies with proficiency levels and task complexity. Strategic instruction is a pedagogical approach that emphasizes explicit teaching of cognitive and metacognitive strategies to enhance learners' ability to plan, monitor, and evaluate their language learning. Drawing on cognitive theory, metacognition, and social constructivism, this approach has been widely explored in English language teaching (ELT) for its effectiveness in promoting reading, writing, and communicative competence. This paper reviews theoretical foundations, instructional principles, empirical evidence, and classroom implications, highlighting the benefits and challenges of implementing strategic instruction in diverse educational contexts. The article also discusses the evolution of language assessment, advocating for **performance-based evaluations** and **technology integration**. Authentic assessment has gained prominence as an alternative to traditional testing in English language education. By requiring students to perform tasks that reflect real-life language use, authentic assessment evaluates communicative competence in meaningful contexts rather than discrete linguistic skills. This article explores the theoretical foundations, principles, advantages, and practical challenges of authentic assessment, presenting evidence from current research in English language pedagogy. **Authentic assessment**, which simulates real-world scenarios, helps develop critical thinking and problem-solving skills, aligning language learning with professional needs. Successful implementation requires well-trained teachers and carefully designed tasks.

Keywords: Military English, specialized English, authentic assessment, strategy, strategical instructions, authentic tasks.

Introduction

Military English teaching refers to the specialized instruction of the English language tailored for military personnel. It focuses on the vocabulary, structures, and communication skills necessary for effective operation in multinational environments, including peacekeeping missions, joint military exercises, and international operations.

Unlike general English courses, military English emphasizes terminology related to defense, tactics, logistics, commands, and emergency procedures. It also includes training in listening and speaking under pressure, understanding radio communication protocols, and interpreting written materials such as manuals, reports, and mission briefs.

With English being the working language of organizations like NATO and the United Nations, proficiency in military English enhances cooperation, interoperability, and mission success in international military settings.

Discussion

The task of teaching specialized English is challenging since it requires bridging the gap between general language proficiency and the unique linguistic demands of certain courses. Specialized fields, unlike ordinary English, may possess distinct lexicons, speech patterns, and modes of communication [1, p.93-108].

The studies demonstrate that Military English language programs in the English as a second language (ESL) or EFL in military settings utilize a range of approaches, including Content and Language Integrated Learning (CLIL) and Task-based Language Teaching (TBLT) (Richards and Rodgers 2014), along with Military English terminology instruction, the use of Information and Communication Technology (ICT) tools, and learning strategies. Research highlights CLIL and TBLT as promising approaches for enhancing learners' lexical knowledge and proficiency in the military contexts. Studies by Finardi et al. (2016) and Nilsson and Lundqvist (2022) demonstrate that CLIL can facilitate multifaceted skill development, both productive and receptive, by engaging officers in content and tasks that reveal knowledge gaps, thereby motivating them to improve. However, they also indicate challenges regarding collaboration between content teachers and language teachers, and a need for more quantitative research on the efficacy of CLIL in improving Military English proficiency. In contrast, TBLT research indicates that tiered tasks and heterogeneous groupings can enhance motivation and learning outcomes (Hung and Chao 2021; Park 2016). Meanwhile, the effectiveness of both teaching approaches seem to vary based on learners' proficiency levels, the content of the task, and level of difficulty. Park (2016) also indicates the need to create safe learning environments where learners can

engage in tasks without fear of 'losing face,' providing some insights into the dynamics of the learning environment of the military setting [2, p.10].

Traditional English language classrooms often emphasize the delivery of linguistic content: grammar, vocabulary, model texts, and literary analysis. While these elements are essential, they do not always equip learners with strategies to navigate unfamiliar or complex language tasks. Strategic instruction reframes language learning as a process that students can consciously manage. By explicitly teaching learners how to approach reading, writing, and communication, teachers foster autonomy, adaptability, and resilience (Paris, Wasik, & Turner, 1991; Zimmerman, 2000) [3],[4]. These competencies are particularly critical in multilingual environments, where students must negotiate meaning across academic, social, and digital spaces.

Strategic Instruction

Strategic instruction has gained prominence as part of a broader shift toward learner-centered pedagogy. Rather than treating students as passive recipients of knowledge, strategic instruction positions them as active problem solvers who can reflect on their learning processes. This perspective is aligned with cognitive psychology, theories of metacognition, and sociocultural understandings of learning. Let's go back to the theorical foundation of the Strategic instruction.

1.Cognitive Theory

Cognitive theory examines how learners receive, store, and manipulate information. In language learning, strategies such as taking notes, summarizing key points, or identifying patterns help students reduce cognitive load and retain information more effectively. Oxford (1990) describes cognitive strategies as "operations or steps used by learners to facilitate the acquisition, storage, retrieval, or use of information" [5, p.8]. These strategies are task-oriented, aiding comprehension and production by organizing linguistic elements.

Reading comprehension research is especially illustrative. When students use predicting, questioning, or synthesizing, they actively process text rather than passively absorb information. This active engagement improves both short-term understanding and long-term retention [6. p.73-80].

2. Metacognitive Theory

Metacognition focuses on learners' awareness and regulation of their cognitive processes. Flavell distinguished between knowledge about cognition and regulation of cognition. The latter includes planning how to approach a task, monitoring progress, and evaluating outcomes. These processes can be explicitly taught, modeled, and practiced in the classroom [7, p.907-908].

In ELT contexts, metacognitive strategies enable learners to anticipate language challenges, choose appropriate tools, and adjust their approaches in real time. For example, a learner who encounters an unfamiliar word may decide whether to use context clues or consult a dictionary. Over time, these decisions become more efficient and deliberate [8, 3].

3. Social Constructivism

Strategic instruction also reflects sociocultural theories of learning. Vygotsky argued that knowledge is co-constructed through social interaction and mediated by cultural tools [9.p.79-85]. Teachers scaffold students' learning, providing support as students develop strategies independently. Peer collaboration—through group reading, reciprocal teaching, or cooperative writing—allows learners to externalize thinking and negotiate meaning with others.

Strategic Instruction in English Language Teaching

1. Reading

Research on strategic reading has been extensive. Palincsar and Brown's reciprocal teaching model illustrates how four core strategies—predicting, clarifying, questioning, and summarizing—enhance monitoring and comprehension [10, 117–118]. Readers learn to anticipate meaning, identify breakdowns, and integrate key information across a text. These strategies are particularly effective for multilingual learners and students with low literacy proficiency.

2.Writing

Writing presents cognitive and linguistic challenges. Students must generate ideas, organize arguments, and revise for audience clarity. The Self-Regulated Strategy Development (SRSD) model integrates planning, drafting, and self-evaluation with motivational components, and has demonstrated strong results among English learners and students with learning difficulties [11, p.7-10]. By breaking complex tasks into manageable phases, SRSD fosters confidence and reduces anxiety.

3.Listening and Speaking

Strategic instruction also applies to oral communication. Canale and Swain emphasized "strategic competence," which includes repair strategies such as paraphrasing, asking for clarification, and negotiating meaning [12, p.3-8.]. Teaching these strategies gives learners practical tools for authentic conversation, especially when vocabulary gaps or misunderstandings arise.

Authentic Assessment

Traditional assessment tends to rely on discrete-point testing and standardized examinations, which measure linguistic knowledge but often fail to assess the ability to use language communicatively.

Authentic assessment, in contrast, evaluates students' performance through tasks closely aligned with real-world language demands—such as writing emails, conducting interviews, or engaging in debates. This shift reflects a broader evolution toward communicative and learner-centered approaches in language education.

The discipline of language assessment and evaluation is undergoing a substantial transformation in order to meet the demands of specialized English instruction (Dang et al., 2023). The recognition that language proficiency encompasses more than just fundamental communication abilities has prompted a quest for novel approaches that can cater to the constantly evolving demands of many professional domains. Educators are experimenting with different strategies to ensure that

learners not only acquire language competency but also develop expertise in applying it within the intricate contexts of their chosen domains. These strategies include performance-based evaluations, the use of technology, and a concentration on ongoing review. As we traverse this evolving terrain, it becomes evident that the fusion of targeted English instruction and sophisticated language evaluation methodologies is vital in equipping people for triumph in our linked and specialized global society [13, p.3].

Authentic assessment evaluates students' ability to apply their knowledge and skills in real-life contexts. It involves carefully designed tasks that reflect genuine situations, requiring students to use critical thinking, problem-solving, communication, collaboration, and creativity. These skills are crucial for both employability and promoting lifelong learning.

A key benefit of Authentic Assessment is its capacity to reflect real-life situations and challenges. In contrast to traditional methods that mainly assess theoretical understanding, authentic tasks simulate scenarios students may face in their professional or everyday lives. This practical connection enhances the learning experience by helping students recognize the real-world value of what they are learning [14, p. 22].

Principles of Authentic Assessment

Scholars emphasize several core principles that differentiate authentic assessment from traditional testing:

1. **Real-world relevance**: Tasks resemble actual communicative events.
2. **Integration of skills**: Reading, writing, listening, and speaking are often combined [15, 390].
3. **Process-oriented evaluation**: Focus on both development and final products.
4. **Student-centeredness**: Learners reflect on performance and take ownership of learning
5. **Alignment with instruction**: Assessment is embedded in learning activities, not added afterward.

Advantages of Authentic Assessment in English Learning

Authentic assessment has a number of advantages, which include: the ability to track individual achievements of learners throughout the educational process (as opposed to simply stating results based on standard benchmark norms); the possibility of informal expert assessment of educational outcomes, such as by employers, parents, educators, as well as self-assessment and peer assessment (in contrast to assessment solely by the teacher); a focus on the learner's achievements, on what they know and can do, which creates a "success effect" (as opposed to a "failure effect," which highlights what the student cannot do); qualitative rather than quantitative (normative, on a scale from 1 to 5) assessment of learning outcomes; and a clear representation of achieved learning outcomes and personal achievements in the form of project products, presentations, and so on [16, p.288].

Authentic tasks are valuable in fostering communicative competence by assessing learners' ability to use language in real-world contexts. Unlike standardized tests, which fail to capture pragmatic and discourse skills, performance-based assessments help learners develop these essential abilities. Furthermore, authentic tasks promote higher-order thinking by requiring students to plan, synthesize information, and make decisions—processes that encourage deeper learning and support the transfer of skills across various contexts. These tasks also increase student motivation and engagement, as they are more meaningful and closely tied to real-life goals. When activities align with students' personal or professional interests, they are more likely to engage and be motivated to communicate. Finally, authentic assessment offers the opportunity for rich, descriptive feedback. Tools like portfolios and project-based tasks provide insight into a student's developmental progress, enabling teachers to offer more specific and targeted feedback for further improvement.

Incorporating Authentic Assessment effectively into an educational setting of College English involves several key considerations that form a cohesive strategy. It starts with teacher training, ensuring that educators possess the necessary knowledge and skills to implement Authentic Assessment successfully. Equipping teachers with the tools to design and evaluate authentic tasks is paramount to its effectiveness. Task design is another crucial aspect of Authentic Assessment. The creation of authentic tasks that align with learning objectives is essential. These tasks should not only mimic real-world challenges but also promote critical thinking among students. The alignment between the tasks and learning objectives ensures that Authentic Assessment serves its purpose of enhancing learning [17, p.76].

Common Forms of Authentic Assessment

Several strategies have been widely implemented in English classrooms:

✧ **Portfolios**: Curated collections of student work demonstrating progress over time [18, p.171].

✧ **Project-Based Assessment**: Research presentations, multimedia projects, or community interviews.

✧ **Performance Tasks**: Role-play, debates, oral presentations, and dramatizations.

✧ **Peer and Self-Assessment**: Reflective journals, rubrics, and collaborative review.

✧ **Real-World Writing Tasks**: Letters, resumes, editorials, and digital media communication.

These forms assess both linguistic ability and communicative competence, offering a multidimensional view of learning.

Challenges in Implementation

✧ *Scoring Reliability*

Authentic assessment often involves subjective judgment, which can produce inconsistent scoring. The use of clearly defined rubrics and teacher training mitigates this challenge.

✧ *Time and Resource Demands*

Authentic tasks require more time to design, implement, and evaluate. Teachers must balance instructional time and administrative expectations [15, 391]

✧ *Institutional Constraints*

Education systems focused on standardized exams may undervalue performance-based assessment.

Teachers must demonstrate how authentic assessment links to curricular outcomes.

✧ *Teacher Readiness*

Effective implementation requires teachers to be familiar with task design, rubric development, and formative feedback practices. Professional development is essential.

Pedagogical Recommendations

To design effective assessments, it's important to begin by ***aligning tasks with clear learning objectives,*** ensuring that the activities target the specific skills and knowledge students are expected to develop. One effective approach is to use ***analytic rubrics,*** which provide detailed criteria that describe student performance at various levels, offering a comprehensive understanding of their strengths and areas for improvement. Assessment should not be a separate, disconnected event but ***integrated with the instructional process*** itself. By allowing assessment to be part of everyday learning, students receive timely feedback and have the opportunity to reflect on their progress, enhancing their learning experience. ***Encouraging student voice*** plays a crucial role in this process. Students should be given opportunities to engage in self-reflection, set personal learning goals, and analyze their own performance. This not only increases their ownership of the learning process but also helps them develop critical thinking and metacognitive skills. Additionally, it's important to ***balance authenticity*** with practicality when designing assessments. While tasks should be realistic and meaningful, they must also remain manageable and yield measurable evidence of learning. This approach ensures that assessments are not only relevant but also effective in evaluating student progress toward achieving learning outcomes.

Conclusion

Strategic instruction shifts English teaching from content delivery to cognitive empowerment. By explicitly teaching learners how to plan, monitor, and evaluate their language tasks, educators help build autonomous and self-regulated learners. In rapidly evolving linguistic environments, these skills enable learners to adapt, communicate, and learn beyond the classroom.

Authentic assessment reflects a shift toward meaningful, communicative language education. By evaluating students in contexts that resemble actual communication, teachers can better measure competence, promote student motivation, and support deeper learning. While challenges such as subjectivity and institutional barriers persist, research suggests that authentic assessment—when thoughtfully implemented—can significantly enhance English language learning outcomes. Continued development of assessment frameworks, teacher training, and policy support will be crucial to its broader adoption.

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THE PROCESS OF IMPLEMENTING STUDENT-CENTERED LEARNING IN UNIVERSITIES OF KAZAKHSTAN

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ПРОЦЕСС ВНЕДРЕНИЯ СТУДЕНЧЕОЦЕНТРИРОВАННОГО ОБУЧЕНИЯ В ВУЗАХ КАЗАХСТАНА

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Abstract

In the context of the modernization of higher education in Kazakhstan, the introduction of student-centered learning (SCL), which focuses on the active participation of students in the educational process, is of particular importance. The purpose of this article is to analyze the theoretical foundations and practical mechanisms for implementing SCL in domestic universities. The key principles of this approach are discussed: individualization of educational trajectories, development of critical thinking, development of skills for independent search and analysis of information, and strengthening the role of feedback between students and teachers.

Particular attention is paid to the institutional conditions necessary for the successful implementation of SCL: updating curricula, using interactive teaching methods, digitalization of the educational environment, and advanced training for faculty. The article emphasizes that the transition to a student-centered model requires a change in pedagogical culture, where the teacher acts not only as a source of knowledge but also as a facilitator, mentor, and partner in learning. Based on an analysis of the practices of Kazakhstani universities, we identified both positive results from implementing student-centered learning (increased student motivation, improved learning, and the development of soft skills) and existing challenges, including limited resources, insufficient faculty preparedness, and the need for systemic support at the educational policy level.

Thus, the implementation of student-centered learning is considered a strategic vector for the development of higher education in Kazakhstan, ensuring its competitiveness and compliance with international standards.

Аннотация

В условиях модернизации высшего образования Казахстана особое значение приобретает внедрение студентоцентрированного обучения (СЦО), ориентированного на активное участие обучающихся в образовательном процессе. Цель статьи заключается в анализе теоретических основ и практических механизмов реализации СЦО в отечественных вузах. Рассматриваются ключевые принципы данного подхода: индивидуализация образовательных траекторий, развитие критического мышления, формирование навыков самостоятельного поиска и анализа информации, а также усиление роли обратной связи между студентом и преподавателем.

Особое внимание уделяется институциональным условиям, необходимым для успешного внедрения СЦО: обновлению учебных планов, применению интерактивных методов преподавания, цифровизации образовательной среды и повышению квалификации профессорско-преподавательского состава. В статье подчеркивается, что переход к студентоцентрированной модели требует изменения педагогической культуры, где преподаватель выступает не только источником знаний, но и фасилитатором, наставником и партнёром в обучении.

На основе анализа практики казахстанских вузов выявлены как положительные результаты внедрения СЦО (рост мотивации студентов, повышение качества усвоения материала, развитие soft skills), так и существующие трудности — ограниченные ресурсы, недостаточная готовность преподавателей и необходимость системной поддержки на уровне образовательной политики.

Таким образом, реализация студентоцентрированного обучения рассматривается как стратегический вектор развития высшего образования Казахстана, обеспечивающий его конкурентоспособность и соответствие международным стандартам.

Keywords: student-centered learning, higher education in Kazakhstan, educational trajectory, interactive teaching methods, digitalization of education, pedagogical culture, student motivation, quality of education.

Ключевые слова: студентоцентрированное обучение, высшее образование Казахстана, образовательная траектория, интерактивные методы преподавания, цифровизация образования, педагогическая культура, мотивация студентов, качество обучения.

Higher education is undergoing significant changes in the modern world, and one of the key trends is the transition from the traditional teacher-centered model to student-centered learning (SCL). This approach places the student, their individual needs, interests, and developmental trajectory at the center of the educational process. SCL aims to develop students' critical thinking skills, independence, creativity, and the ability to engage in lifelong learning. In the context of global competition and national development strategies, the implementation of SCL is becoming a priority for Kazakhstan's universities, as it directly impacts the quality of specialist training and their competitiveness in the labor market.

The purpose of this article is to evaluate the implementation of student-centered learning in Kazakhstan's universities based on empirical data obtained during accreditation procedures. The primary empirical base is the reports of external expert groups of the Independent Kazakhstan Accreditation Center on 14 domestic higher education institutions, completed as part of specialized and institutional accreditation in 2024.

To achieve this goal, the following tasks were defined:

1. To identify the overall picture and typical problems that universities face when implementing SCL.

2. To analyze specific examples of successful implementation and systemic shortcomings at the level of individual universities.

3. To summarize the data obtained and formulate conclusions, as well as to propose practical recommendations for educational organizations and the authorized body in the field of higher education.

The object of the study is the process of ensuring the quality of higher education through the use of accreditation procedures, and the subject is the process and results of the implementation of student-centered learning in accredited educational organizations.

The research methodology is based on a qualitative approach, including thematic analysis and data synthesis from reports, as well as comparison of identified practices to identify common trends and unique characteristics.

The structure of the paper includes an introduction, two main sections (a description of the key ideas of student-centered learning and a detailed analysis of universities), and a conclusion containing key findings and recommendations. This approach will allow for a comprehensive examination of the current state of student-centered learning in Kazakhstan and identify paths for its further improvement.

Student-centered learning has its roots in the early 20th century, when it was proposed by F.H. Hayward in 1905.[1] It was further developed in the works of John Dewey (1956). In the 1980s, Carl Rogers transformed SCL into an educational theory based on the principles of humanistic psychology, which proposes learner-centered (person-centered) learning, opposed to the traditional, authoritarian system. Rogers believed that every person has an innate desire for growth and self-actualization , and education should be a facilitating environment where students actively participate in the learning process, make independent decisions and develop their inner potential.[2] SCL is also associated with the works of Jean Piaget (developmental learning) [3] and Malcolm Knowles (self-directed learning) [4].

In Soviet pedagogy and psychology, student-centered learning is closely linked to the student-centered approach, the ideas of collaborative pedagogy (Amonashvili Sh.A., Ilyin E.N., Shatalov V.F., and others), developmental learning (Vygotsky's zone of proximal development), Davydov V.V., Zankov L.V., and Elkonin D.B. They are all united by key ideas, including the active participation of the student in his or her learning and development, freedom of choice, creative activity, and collaborative work with the teacher, the development of critical and theoretical thinking, and an individual approach to each student.

The handbook " **Student-Centred Learning. A Guide for Students, Staff and Higher Education Institutions. European Students' Union. Brussels, October 2010"** provides the following definition: "Student-centred learning represents both a way of thinking and a culture within a particular higher education institution and an approach to teaching that is broadly linked to a learning theory based on constructivism. It is characterized by innovative teaching methods that aim to promote learning based on collaboration between teachers and students, promoting an active role for students in controlling their own learning process, thus contributing to the development of personal skills such as problem solving, critical and reflective thinking."[5;5]

In our thematic analysis, we will use this definition as the basis for analyzing and summarizing the activities of accredited educational programs. An analysis of the extensive scientific literature on student-centered learning allowed us to identify the following components of student-centered learning:

1. **Equal student participation in governance:** Student representatives should be involved in all decisions concerning their social and academic activities, including serving on appeals committees, internal audit working groups, and curriculum development boards. In the IKCA's specialized accreditation standards, this component is assessed through an analysis of the criteria of Standard 1—Policy for Quality Assurance of the Educational Program; Standard 3—Student-Centered

Learning, Teaching, and Assessment; Standard 7—Information Management and Public Dissemination; and Standard 8—Regular Monitoring, Periodic Evaluation of Educational Programs, and Periodic Accreditation.

2. **Flexible curricula and individual learning paths are** one of the key components of student-centred learning, which we have included in the criteria of Standard 2 – Development and approval of educational programmes, Standard 3 – Student-centred learning, teaching and assessment, Standard 6 – Resources and student support, and Standard 8 – Regular monitoring, periodic evaluation of educational programmes, periodic accreditation.

3. **Expected learning outcomes (ELs)** are a set of competencies that express what students will know, understand, and be able to do upon completion of the learning process. These competencies include both professional and core competencies. The analysis and evaluation of criteria for almost all IKCA Accreditation Standards focuses on this component of the SCL. The most prominent criteria are those of Standard 2—Development and Approval of Educational Programs; Standard 3—Student-Centered Learning, Teaching, and Assessment; and Standard 4—Student Admission, Academic Performance, Recognition, and Qualifications.

4. **Assessment and feedback** at the end of learning activities should be two-way. Through transparent feedback, students assess whether expected learning outcomes have been achieved and actively participate in defining and revising them for subsequent groups of students in the same course. Teachers, in turn, assess whether students have achieved the minimum requirements, as well as any additional learning outcomes, which will then be included in the Diploma Supplement. This component of the SCL, closely related to the previous one, is assessed more closely when analyzing the criteria of Standard 3 – Student-Centred Learning, Teaching, and Assessment, and Standard 4 – Student Admission, Progress, Recognition, and Qualifications.

5. **Student awareness of student-centered learning.** All students, regardless of their major or year of study, should be aware of student-centered learning. They should understand the concept, its principles, and its components. The analysis and assessment of this component is primarily based on the criteria of Standard 1 – Quality Assurance Policy for the Educational Program, Standard 3 – Student-Centered Learning, Teaching, and Assessment, and Standard 4 – Student Admissions, Academic Performance, Recognition, and Qualifications.

6. **Professional development of teachers.** Professional development programs for teachers should be aimed at ensuring that they are able to apply a variety of innovative teaching methods, tailored to the learning styles and needs of different student groups, and that they possess competencies in inclusive education. The criteria of Standard 5 – Faculty – focus heavily on the analysis and evaluation of this important component of the SCL.

7. The use of information and communication technologies for the development of the SCLS and the technological automation of the educational process. To analyze and evaluate this crucial component of the SCLS, the IKCA primarily uses the criteria of Standard 6 – Resources and Student Support, and Standard 7 – Information Management and Public Information.

8. **Student Participation in Quality Assurance.** Active student participation should be a mandatory principle of quality assurance in educational institutions. Students should be recognized as competent and equal partners and serve as active members of decision-making bodies for internal and external quality assurance. The IKCA uses the criteria of Standard 1 – Policy for Quality Assurance of the Educational Program, Standard 2 – Development and Approval of Educational Programs, Standard 3 – Student-Centered Learning, Teaching, and Assessment, and Standard 8 – Regular Monitoring, Periodic Evaluation of Educational Programs, and Periodic Accreditation to analyze and evaluate quality assurance for the implementation of this component of student-centered learning.

9. **Internal assessment of the quality of assessment methods.** As part of the internal assessment of program quality, the university must pay special attention to the quality of assessment methods. This should emphasize the student's learning outcomes compared to the expected learning outcomes formulated during the curriculum development process. To analyze and assess this aspect, the IKCA uses the criteria of Standard 1 - Educational Program Quality Assurance Policy, Standard 3 - Student-Centered Learning, Teaching, and Assessment, and Standard 4 - Student Admissions, Academic Performance, Recognition, and Qualifications.

10. **Social Dimension.** The social dimension should become an integral part of the educational process and concern not only access to higher education but also successful progression through all levels, encompassing all periods of the student life cycle at each level. One of the most important elements in this regard is the adaptation of teaching methods to different student groups. It is essential to consider the individual characteristics and learning styles of different student groups, particularly students from disadvantaged backgrounds, students with special educational needs, including those with disabilities, or young parents. To analyze and evaluate quality assurance in this aspect, the IKCA uses the criteria of Standard 3 – Student-Centered Learning, Teaching, and Assessment; Standard 4 – Student Admission, Academic Performance, Recognition, and Qualifications; Standard 5 – Teaching Staff; and Standard 6 – Resources and Student Support.

11. **Student support services.** Working students or those with children should be provided with opportunities for creating a more flexible learning path and possibly allowing you to extend your studies in order to effectively combine studies, work and/or family. Students should have free access to appropriate research and teaching equipment during their studies, receive timely information about changes in the educational process, and receive academic support in the event of problems meeting academic requirements. The IKCA uses criteria from a number of standards to analyze and

evaluate quality assurance for this component of the SCL: Standard 3 – Student-Centered Learning, Teaching, and Assessment; Standard 4 – Student Admissions, Academic Performance, Recognition, and Qualifications; Standard 6 – Student Resources and Support; and Standard 7 – Information Management and Public Outreach.

12. **Student mobility.** This crucial component of the SCL, aligned with one of the key requirements of the Bologna Process for the internationalization of education, is typically included in the Development Strategies of Higher Education Institutions. Therefore, to analyze and assess the quality of this component of the SCL, the IKCA uses the criteria of Standard 1 – Policy for Quality Assurance of the Educational Program; Standard 3 – Student-Centered Learning, Teaching, and Assessment; Standard 4 – Student Admission, Academic Performance, Recognition, and Qualifications; and Standard 5 – Faculty.

13. **Recognition.** Credits earned through academic mobility and informal learning should be recognized without bureaucratic delays. A Diploma Supplement (DS), certifying the student's qualifications, including the learning outcomes and context, should be issued automatically and free of charge upon completion or upon request before completion at each higher education institution. The document should follow a standard model, clearly stating the learning outcomes achieved, including any additional credits and/or unforeseen learning outcomes. To analyze and evaluate this aspect of the SCL, the IKCA uses the criteria of Standard 3—Student-Centered Learning, Teaching, and Assessment, and Standard 4—Student Admission, Progress, Recognition, and Qualifications.

Analysis of EEG reports within the framework of the SCL

Since our goal is to identify the overall picture and typical problems that universities face when implementing student-centered learning, in order to comply with the requirements for confidentiality of information obtained during the accreditation process by the Independent Kazakhstan Center of Accreditation (IKCA) of educational organizations and educational programs in this thematic analysis, we will encode the names of specific universities using letter designations.

University A claims to attract specialists in the 6B06138 "Information Systems" program, but in reality, faculty lack opportunities for international academic mobility. The lack of an internship program for faculty and the fragmented nature of research topics and publications indicate an unsystematic approach to staff development, which undermines the ability to implement such a crucial requirement for student-centered learning as professional development for faculty, which directly impacts the quality of student learning.

University B faces challenges in implementing specialized learning environments in programs including **6B03201** "Journalism," 6B04104 "Finance," 6B04103 "Economics," and 6B04101 "Management." Students in these programs do not participate in academic mobility, and research is weak, with specialized classrooms underequipped. However, a multimedia journalism studio and an educational television studio are effectively utilized.

As in other accredited universities, the social dimension is effectively implemented in terms of inclusive education and access to education for individuals with disabilities. The university's Legal Consultation Clinic has provided positive experiences in providing free psychological support and legal consultations to students. Unfortunately, the lack of student involvement in the development of educational programs violates one of the most important requirements of the SCL—"equal student participation in governance." Specifically, student representatives should actively participate in appeals committees, internal audit working groups, and boards responsible for curriculum development.

The private institution "University C" is demonstrating positive trends. A robust system of specialized classrooms and the active involvement of corporate partners in practical training demonstrate a high-quality, practice-oriented approach. Social support for students, particularly those with disabilities, and a wide range of grants and benefits in accordance with the Regulation on Social Support for Students make education more accessible, an important element of the SCL.

Effective work is underway to achieve expected learning outcomes through external program reviews by employers, evaluation, and feedback through regular student surveys and questionnaires to revise program content with the participation of students, graduates, and employers. Serious attention is paid to the professional development of faculty through internships, internal professional development through weekly educational and methodological seminars, and a mentoring system.

The University of D provides ample opportunities for external and internal academic mobility of students with well-established procedures for credit transfer and recognition of earned credits.

To implement the requirement of a "social dimension," to improve social protection and the standard of living of students, the university has a Social Package, which provides benefits for tuition fees, financial assistance in various family and health circumstances, and incentives for high performance in academic, athletic, research, and social activities.

The university places particular emphasis on supporting socially vulnerable students, providing them with targeted social support and socio-psychological assistance:

- more than 25 students were awarded an internal rector's grant;
- 31 students (orphans) received monthly assistance in the form of financial assistance for food and clothing (up to 100 thousand).
- orphans and disabled students live in student houses free of charge.

The university places great emphasis on incentivizing faculty and staff for their professionalism and dedication. A system of financial incentives for faculty based on rankings and KPIs has been developed and implemented.

Feedback has been established between students and the university administration through the functioning of blogs (rector, deans, admissions committee).

The system for assessing relationships with students and employers and analyzing their needs is designed in such a way that learning outcomes are updated or changed in accordance with the results of a survey of employer satisfaction with the level of training of graduates.

The main drawback of this university is the lack of practical training in classes, for example, in the 7M05101 "Biology with Fundamentals of Microbiology" program . This deprives students of applied knowledge and discrepancies between student learning outcomes and the demands of the modern labor market. The university's educational programs have only just begun to implement micro-qualifications , which reduces the potential for flexible programs and individualized educational trajectories.

University E ensures the successful implementation of the SCL. Assessment and feedback during systematic quality monitoring through surveys on satisfaction with learning outcomes enables , with the participation of students and employers, changes to educational programs regarding planned learning outcomes and assessment methods. The successful implementation of the external and internal academic mobility program demonstrates an effective approach to meeting student needs. Student support services, like those at other accredited universities, operate effectively, ensuring inclusive education for individuals with disabilities: like all 13 other universities, tactile pathways, ramps, lifts, and designated parking spaces are available. Social support is provided to students from vulnerable groups (orphans, those from large low-income families, and individuals with disabilities). As in other universities accredited by the IKCA, this university implements a high level of use of information and communication technologies, licensed educational programs such as AutoCAD, MidasCivil, and others. Technological automation of the educational process is carried out using the automated information system "Platonus".

However, as in other universities, insufficient attention is paid to timely work to inform students about the features of student-centered learning in accredited educational programs. Therefore, students are formally involved in the work of the Academic Council and academic committees for the development of educational programs.

Institution "University F"

To ensure equal participation in governance, the university has developed a system for assessing the effectiveness of its mission, goals, and objectives. This system is implemented across all departments and involves all employees, external stakeholders, and students. The university has a well-developed internal quality assurance system, a culture of academic integrity, and a functioning quality management system.

Regarding expected learning outcomes, for example, the 6B05202 Ecology (Bachelor's) program is developed within the context of a competency-based model of specialist training and is focused on learning outcomes expressed as competencies. The program is designed using a modular principle. Each module is focused on achieving a specific learning outcome, that is, a competency. Learning outcomes are formulated for the program as a whole, for each module, and for each individual course.

In the 2022-2023 academic year, the final assessment format was revised: a thesis project was introduced, resulting in the student's work representing an independent solution to applied problems relevant to the educational program profile, completed using project-based approaches such as business projects, models, creative projects, and other projects. A QR code encryption system was introduced, using combined forms of the comprehensive exam.

To carry out assessment, feedback, and identify stakeholder needs, the university receives from employers, for example, letters of gratitude for the training of students in the "Standardization, Certification, and Metrology (by Industry)" program, expert opinions on the educational program 6B07502 "Standardization, Certification, and Metrology (by Industry)", etc.

Academic mobility among students is poorly developed (external mobility is completely absent). Student engagement in research is low. The university's website lacks information about students' research activities, certificates, or diplomas—that is, supporting documents confirming students' involvement in research.

To support the professional development of young teachers, the university has established and operates a "Young Teacher School," which oversees the work of newly arrived teachers and provides them with methodological support.

Information support for students and teachers is provided on the basis of the Information and Analytical Complex for Managing the Educational Process "Electronic Rector's Office" and the official website http://nku.edu.kz, which are integrated with each other.

The University faces problems with academic mobility and research work in the programs 6B05202 "Ecology" , 6B07502 "Standardization, Certification and Metrology (by industry)", 6B07302 "Design and Information Modeling of Construction Projects" .

At the Institution "University G" , in the direction of the SCL "Equal Participation of Students in Management", master's students of the EP "7M04112 - State and Local Government" take part in the management of the university, are part of collegial bodies, make proposals for making management decisions, improving the educational and methodological, scientific and educational process.

Students as part of its "Assessment and Feedback" system. This method is characterized by capturing and assessing expectations and interests related to the university's educational program. Surveys, questionnaires, and other methods are traditionally used to collect relevant information. Based on student data—identifying their interests, identifying their strengths and weaknesses, and interacting with the educational program—the prospects for a long-term development program for the educational program are determined, ensuring increased competitiveness in the educational market.

In the area of the SCL "Expected Learning Outcomes," the procedure for developing the EP "7M04112-State and Local Government" and planning learning outcomes is carried out collegially and transparently, taking into account the scientific interests of the teaching staff, proposals from stakeholders, primarily students included in the working group of the Academic Committee, as well as existing expert opinions on the educational program.

The implementation plan for the integrated Social Dimension SCL, designed to ensure equal opportunities and accommodate individual needs in achieving learning outcomes, study additional subjects, and repays academic debt, includes a summer semester, and allows for enrollment in additional courses. The university promotes inclusive education and offers substantial support to students with disabilities and from low-income families through discounts and rector's grants. The university has created all the necessary learning conditions for individuals with special needs: library space, ramps, elevators, and designated parking spaces.

In terms of implementing the professional development of teachers, the management of EP 7M04112 "State and Local Government" pays attention to improving the qualifications and training of teaching staff in innovative educational technologies and methods that promote professional development and allow them to be constantly informed about the latest changes in their field of activity.

The university provides compensation for expenses for publication in foreign scientific journals and provides for publication in the international databases Scopus and/or Web of Science.

At the same time, this university has the same fundamental problems identified in a number of other universities - a low level of academic mobility of master's students in programs 7M04112 "Public and Local Administration" and 7M04122 "Economics ," as well as ineffective career guidance. This leads to low enrollment of master's students, indicating the programs' lack of appeal and the ineffective implementation of the vocational school system.

At the Institution "University H"

In the direction of "Expected learning outcomes", when developing the educational program 7M01703-Foreign language: two foreign languages, the principles of continuity, succession and consistent increase in requirements for learning outcomes based on competencies with the active participation of master's students in this program were used.

The system for assessing relationships with employers and analyzing their needs is designed in such a way that learning outcomes are updated or changed in accordance with the results of a survey of employer satisfaction with the level of training of graduates, in accordance with employers' proposals, using the results of a survey primarily of consumers of educational services - students.

This university is actively developing social support for students, including those with disabilities. To this end, faculty members have completed courses on inclusive education.

As in many other accredited universities, resource provision allows for the effective use of information and communication technologies for the development of the SCL, and all the capabilities of the automated information system "Platonus" are used for the technological automation of the educational process.

However, this university lacks a systematic approach to the scientific work of teachers, which negatively affects the quality of education in the field 7M04103 "Accounting and Audit" means that an important area of the SCL—"Professional Development of Teachers"—is not being effectively implemented. The insufficient provision of educational and methodological resources for the programs is also a serious obstacle to an effective SCL.

Institution "University I"

In the area of "Expected Learning Outcomes," Academic Committees, which include students from this university, engage employer representatives when developing programs to determine learning outcomes that align with the competencies required by the modern labor market, particularly for EP 6B06202—Radio Engineering, Electronics, and Telecommunications , 6B04205—Customs, and others. Roundtables are held annually with the participation of those interested in the development and updating of the EP: student representatives, university administration, department heads, faculty, and employers. Their suggestions are necessarily taken into account when developing and updating the EP.

The university actively provides social support to students, including those with disabilities. For these students, the university has an inclusive education office equipped with the necessary teaching equipment and developed rules for ensuring inclusive education. A full-time specialist has been assigned to staff the office.

In the area of the SCL "Flexible Curricula and Individual Learning Paths," the experience of implementing the additional Minor program "Professionally Oriented English" in one of the programs has been effective.

In the "Use of Information and Communication Technologies for the Development of Information and Communication Technologies and Technological Automation of the Educational Process" program, this university has demonstrated effective experience in implementing innovative educational technologies and methods, for example, in the field of construction, which provide students with the opportunity for more effective learning and development.

1. Use of virtual and augmented reality (VR and AR):

• VR and AR allow construction trainees to immerse themselves in virtual models and simulations of construction projects. This allows them to understand construction processes and make decisions in real time.

2. BIM (Building Information Modeling):

• BIM is a modeling method that enables the creation of three-dimensional models of building projects with detail at every stage of design and construction. This improves collaboration between various project participants and contributes to process optimization.

3. Project-based learning:

• Curriculums that include real-world construction projects allow students to apply their knowledge in practice and acquire skills that will be useful in the job market. This method is used in the 3D modeling and AutoCAD disciplines.

At the same time, this university has serious problems with the implementation of the SCL: as well as in A number of other accredited universities have problems with the implementation of academic mobility of students in certain programs, formal participation of students in the internal quality assurance system, and a lack of equipped specialized classrooms for certain programs.

At University J, we were able to highlight only a few aspects of the 13 aspects of student-centered learning we identified in the reports of external expert groups. Specifically, in the "Expected Learning Outcomes" section, all five accredited programs noted the university's effective collaboration with employers in implementing practice-oriented learning, incorporating learning outcomes in demand in the modern labor market in the southern region of the country, and introducing elements of dual education in certain programs.

In the area of "Professional Development of Teachers," IKCA experts noted that the university has developed an effective system of rewarding teachers and staff for high pedagogical excellence, scientific achievements, and dedication (for example, financial incentives for the scientific work of faculty members for publishing articles in highly ranked journals). Senior faculty members are actively working on the topic of "Monitoring as a Method of Research and Forecasting the Dynamics of Ethnosocial Processes in the Republic of Kazakhstan," and research projects are consolidated at JSC NGNTsT.

However, the academic mobility plan for the "Student Mobility" program in program 6B04202 – Law Enforcement Activity has only just been developed, and no work on external or internal student mobility has been identified for program 6B01506 – Physics and Computer Science. Overall, the implementation of the SCL at this university is very low.

IN University K: In order to implement the requirements of the SCL in terms of flexible curricula, this university offers additional courses in the form of a Minor (Minor) – a set of interrelated subjects of the same profile, different from the main area of training of a teacher – for the educational program "6B01704 – Training of Teachers of Uzbek Language and Literature".

In planning and implementing expected learning outcomes at this university, experts noted that educational programs are focused on learning outcomes. All stakeholders, including employers and students, are involved in the development of educational programs and the monitoring of educational activities within them, and they actively participate in the Academic Program Development Committees.

The "Assessment and Feedback" program at the SCL annually collects feedback from educational service consumers (employers, university graduates, students, and their parents) to determine their satisfaction with the quality of educational services and the transparency of the university's operations. The feedback results are analyzed and discussed at department meetings.

In order to ensure objectivity and openness in internal and external communications, as well as in interactions with applicants, the following feedback channels are in operation: the rector's blog; call center ; helpline; help boxes; and career guidance department.

To implement the "social dimension," the university has created facilities for students with disabilities (access ramps, information and navigation aids, and doors and staircases painted in contrasting colors). Conditions have been created to ensure constant access for students with disabilities and other social groups. The Empathy Center for Psychological Support in the Gagarin Academic Building provides social assistance and psychological and pedagogical support.

The assessment of the conformity of the content and learning outcomes for the recognition of a non-formal education program with the content and learning outcomes of an academic discipline or module is carried out by comparing the formulated learning outcomes and competencies of the compared programs, their volume (in academic hours and academic credits), learning objectives, and assessment of academic achievements.

The main goal of working with faculty and staff at the University is to create conditions for their professional and personal growth. This is facilitated by the development of a system of measures aimed at establishing a comprehensive professional development system for all faculty, ensuring social security for employees, and fostering a positive social environment at the university. The university uses a KPI system—a set of interrelated individual numeric indicators used to evaluate the effectiveness of the faculty.

Internal assessment of the quality of assessment methods is achieved through assessors' knowledge of student knowledge assessment methods and ongoing professional development in this area. In particular, department faculty members completed international online courses for faculty members on teaching and assessing students' knowledge of the Uzbek language and literature. Assessment methods for students' knowledge, skills, and abilities contribute to the achievement of learning outcomes. Methodological recommendations for assessing assignments in the disciplines of the "Training of Teachers of the Uzbek Language and Literature" program have been developed.

To help students understand the specifics of the SCL, the university's website features a "Guide for First-Year Students," which contains information on the basic principles of credit-based learning, the organization and design of the educational process, students' rights and responsibilities, and the activities of advisors.

As the analysis shows, in this university a significantly larger number of SCL elements have been implemented in its activities.

At the **University** In **the direction of the SCL** "Equal Participation of Students in Management", ex-

ternal audit experts noted the active participation of students, along with members of the Academic Council, the Academic Committee, which includes students, the Education Department of the Karaganda Region, and preschool organizations in the implementation, monitoring, and revision of the internal quality assurance system of the educational program.

In the plan for implementing the SCL requirement "Expected learning outcomes", it was revealed that the accredited programs of this university were developed in the context of a competency-based model for training specialists, with competencies corresponding to the Dublin descriptors, taking into account ECTS and the EPVO qualification framework.

In accordance with the requirements for the implementation of inclusive education, the subject "Inclusive Education" has been included in all pedagogical educational programs, and teachers who have completed advanced training in inclusive education are involved in teaching it. A minor has been added to the main program. Program on the features of inclusive education.

In the implementation plan for the composite SCL "Assessment and Feedback", programs are reviewed annually based on an analysis of feedback received from students, employers, graduates and other stakeholders.

The audit revealed that students and employers have repeatedly initiated the introduction of disciplines relevant to the teaching labor market into educational programs. For example, the inclusion of the discipline "Monitoring the Individual Development of Preschool and Primary School-Age Children" demonstrates how proposals from educational stakeholders are quickly reflected in curricula.

The implementation of academic mobility for students is supported, which is regulated by the University's Academic Policy, which provides for the development of a culture of flexible educational trajectories, the development of mechanisms for mutual recognition and the transfer of courses and periods of study, qualifications and degrees in other universities.

To implement the "Recognition" requirement of the SCL, the university provides the opportunity to recognize competencies acquired through non-formal and informal learning, such as internships, professional practice, or independent learning, using competency assessment and verification mechanisms. Recognition of academic credits for mobility purposes is based on the following documents: contract, training agreement; transcript of grades; and internship completion certificate.

As part of the implementation of the "Professional Development of Teachers" component of the SCL, over the past five years, departmental faculty has completed 85 professional development courses. The university provides faculty with the opportunity to participate in internships abroad to exchange experiences with international colleagues. Faculty participates in courses at the Center for Distance Education Technologies, developing the necessary skills for working with the credit-based learning system.

Moral and material incentive systems are in place for faculty. Clear career ladders and development plans have been developed for faculty, allowing them to build long-term plans for the university. A differentiation coefficient for the incentive salary supplement per academic year has been introduced, and individuals are recognized in specific categories, such as the "Best Curator-Advisor" award for the 2020-2021 academic year.

In implementing the "Social Dimension" SCL requirement, special attention is paid to creating conditions for the education of individuals with special educational needs: an inclusive education room has been equipped with modern equipment. This room allows for classes to be conducted with the needs of students with disabilities in mind. A unique collection of materials is available for individuals with visual, hearing, and musculoskeletal impairments. This includes large-print books, electronic audio materials, as well as special workstations, specialized desks, ramps, and digital devices that facilitate access to learning.

At the Institution "University As part of the SCL's "Equal Participation of Students in Management" program **,** experts noted student participation in assessing the quality of teaching and educational programs through surveys and questionnaires, active student involvement in managing the educational process, and the development of proposals for its improvement. Students are members of the Academic and Methodological Council and the Academic Quality Council. According to interviews, the university regularly holds meetings between students, faculty, and the rector to discuss student issues. Students can meet with the rector at any time during the working day, regardless of the time.

In the area of the SCL "Flexible Curricula and Individual Learning Paths" at this university, for example, the accredited EP 6B01422 - "Physical Education and Sport" offers the following individual learning paths: "Theory and Methods of Teaching Physical Education and Sport", "Fundamentals of Teaching Sports Disciplines (Sports Trainer Path)"; "Fitness and Sport" (Fitness Instructor and Healthy Lifestyle Specialist Path), "Management in the Field of Physical Education and Sport".

Through the Student Mobility program, the university implements opportunities for external and internal academic mobility with established procedures for credit transfer and recognition. For example, from 2022 to 2024, a total of 251 students completed external, internal, outgoing, and incoming academic mobility across all programs at the Institute of Pedagogy, Business, and Law, including 114 in the pedagogical program.

To implement the SCL program's "Student Awareness with Student-Centered Learning" program, the university traditionally holds an orientation week for first-year and international students, where they are thoroughly introduced to the university's Academic Policy and the specifics of the student-centered approach to learning.

As part of the implementation of the "Recognition" component of the SCL, if learning outcomes are consistent with the prerequisites of the educational program, individual courses from the previous level of for-

mal education, other types of academic work, and informal learning outcomes are transferred. For example, students who have completed one or more courses on the Coursera platform and received certificates will have their credits subsequently counted towards their educational achievements (20 students from the accredited educational program completed the ICT course on Coursera).

In the implementation plan for the next component of the SCL—"Professional Development of Teachers"—teachers in accredited programs conduct classes using innovative technologies and methods. Two teachers completed courses on inclusion at the National Women's Pedagogical University. Systematic assessment of teacher competence and evaluation of teaching effectiveness at the university as a whole and within departments is implemented through:

– internal assessment (open classes, mutual visits, control visits);

– identifying the opinions of internal consumers (students) about the quality of educational services and the level of competence of the teaching staff;

- external assessment (employer surveys). The university has developed an interconnected system for assessing the effectiveness of teaching quality.

In In the "Expected Learning Outcomes" section of the SCL **, "University M "** operates a system for assessing relationships with employers and analyzing their needs, so that learning outcomes are updated or changed in accordance with the results of a survey on employer satisfaction with the level of training of graduates and students of all programs. During the audit, external audit experts obtained evidence of the participation of students, faculty, and other stakeholders in the development of the educational program and ensuring its quality.
Basic, specialized, and elective disciplines of the educational program 6B04217 "Jurisprudence" are mastered in light of the latest advances in science and practice, which ensures the relevance of the taught disciplines and a clear

compliance with the objectives of the educational program.

The law programs offer practice-oriented training at the department's branches in the Akmola Regional Court and the Akmola Region Department of Justice. Experienced instructors with practical experience in the prosecutor's office, law enforcement, the judicial system, forensics, notarial work, and advocacy work to master the practical aspects of the subjects.

The program **6B02111 "Design"** also implemented a practice-oriented approach to training, classes conducted by leading employees of enterprises and organizations of the region (designer of the regional branch of the "Union of Artists of the Republic of Karelia", designer of the advertising and production company "OLIVIN", designer of the advertising agency "DEI").

As part of the "Social Dimension" and "Student Support Services" programs, the university has established a unique Institute of Exempt Curators—the only one in the northern region—which serves as the primary structure monitoring student attendance and academic performance and implementing educational work. Counselors are available at night in the Student Houses, and social support is provided to students, including those with disabilities. Furthermore, as at other accredited universities, the Student Service Center operates, providing approximately 20 types of services. Construction of the Student Palace and a sports complex, which meets international standards, has been completed. A legal clinic is actively operating, and the laboratory facilities and forensic testing ground are effectively used for joint classes between lecturers and industrial practitioners.

The "Professional Development of Teachers" program at the SCL provides an ongoing system of professional development for faculty using modern information technology approaches (courses in artificial intelligence, neural networks, online and offline teaching methods, etc.). Innovative teaching methods are used, taking into account European experience in conducting classes. Professional development courses offered through the Belgian Education Council have facilitated the application of effective teaching methods, the development of assessment criteria, the implementation of formative assessment, and the stimulation of student reflection. Mentoring is part of all programs, and professional development activities are held for young teachers.

The results of the department's current research, conducted as part of the research school "Theory and Practice of Applying National Legislation in the Context of Legal Reform in the Republic of Kazakhstan," are also being integrated into the educational process. A faculty incentive system based on monthly ratings has been developed, along with a well-established system for in-house professional development (weekly educational and methodological seminars).

The big picture and typical problems

Overall, universities are striving to implement SCLs, but they face a number of systemic challenges. The most common shortcomings include:

1. Regrettably, we note **a formal, superficial approach to the implementation of the two interrelated components of the SCL: "Equal Student Participation in Management" and "Student Participation in Quality Assurance."** The inclusion of one active student (master's or doctoral student) on the Academic Council, Academic Council, or Academic Program Development Committee does not automatically guarantee the implementation of this aspect of the SCL. Clearly, not just one student, but several of the most responsible, authoritative, critically thinking student representatives capable of expressing and defending their position should be included in such councils, committees, and working groups.

2. Insufficient work in accredited universities and programs to implement the minor, micro-qualifications, and nano-credits required by the State Compulsory Education Standard (SCS) would allow students to more effectively develop their educational trajectory, acquiring the professional competencies necessary for the modern labor market. These are problems with the

implementation of the "Flexible Curriculums and Individual Learning Paths" component of the SCS. However, many accredited programs do provide individual trajectories.

3. In the implementation of such an important component of the SCL as "Expected Learning Outcomes" IKCA experts note that program developers have mastered the art of formulating learning outcomes and correctly define methods for assessing the development of learning outcomes during midterm and final assessments. However, a **lack of practice-oriented training is noted:** universities inconsistently engage practitioners, creating a gap between theory and the actual needs of the labor market. Although many universities in the Republic of Kazakhstan are actively working to introduce elements of dual education, no such effective practice has been identified in the programs of the 16 universities accredited by the IKCA.

4. According to experts, the "Assessment and Feedback" function of the SCL is implemented at the required level thanks to, firstly, the use of automated information systems (Platonus, Univer, etc.), which enable students to achieve transparent assessment, track their academic performance, and rank; secondly, well-established monitoring of all aspects of students' educational activities, surveys of educational stakeholders regarding satisfaction with their results, and decision-making on identified issues; and thirdly, the use of information and communication technologies, university websites, and social media (WhatsApp , etc.) for prompt feedback .

5. A review and analysis of external audit reports reveals that universities are underperforming in the most important component of the Student Centered Learning (SCL) system—students' awareness of student-centered learning. Although we have noted the universities' experience in conducting an orientation week for new students, there is no information from experts indicating that they clearly and unambiguously communicate the essence and content of this learning approach to students, nor that they understand students' ability to manage their own educational trajectories. This is clearly why we have noted the long-standing problem **of low academic mobility among students** and faculty.

This is the most acute and common shortcoming. At many universities, students and faculty lack sufficient opportunities to participate in exchange programs, which limits their professional development. This is most often due to a lack of funding for mobility programs, insufficient efforts by departments to find opportunities for students to earn the necessary credits at national and international universities, and, finally, students' ignorance of opportunities to earn the credits they seek at other national universities and universities in neighboring and distant countries.

6. The next component of the SCL, "Recognition," related to mobility, is reflected in reports from external expert groups as having been implemented in terms of recognizing student credits earned through the minimal mobility process noted above. However, unfortunately, widespread experience with recognizing informal education, similar to Coursera programs , has not been found in accredited universities and programs. Although This one from important components of the SCL.

7. In the next important component of the SCL, "Professional Development of Teachers," all accredited universities and programs are implementing the necessary internal and external professional development for teachers, and it is gratifying to note that serious attention is paid to inclusive education. Rankings, material and moral incentives, and the implementation of KPI-based performance assessments are used to stimulate and motivate the professional development of faculty . However, reports from external expert groups only noted the use of innovative educational technologies by teachers, emphasizing the organization of active, independent cognitive activity in students, the development of critical thinking, and technologies that prepare them for independent, lifelong learning.

8. All accredited universities and educational programs effectively utilize information and communication technologies, and have the appropriate software and computer equipment. Technological automation of the educational process has been implemented, leveraging the capabilities of the automated information systems "Platonus," "Univer," and others, and educational portals are operational. University websites, electronic document management, email, and social media are also used to promptly inform participants in the educational process and provide feedback.

9. In terms of implementing the next important component of the Social Dimension SCL, we have already noted the universities' work on inclusive education, adapting teaching methods to different student groups. All universities are creating the best possible conditions for students with disabilities, working students, and young parents, and faculty are receiving advanced training in organizing inclusive education. All universities offer tuition benefits for orphans, students from large families, and students from low-income families, and rector's grants are awarded. Free legal and psychological counseling is also available. This work needs to be continued and expanded.

10. A careful analysis of external expert group reports and self-assessment reports allows us to note that, in our opinion, IKCA-accredited universities and programs are paying insufficient attention to such an important component of the SCL as "Internal Assessment of the Quality of Assessment Methods." Unfortunately, for many years, since 1996, many universities have been using testing, primarily computer-based, for assessment. Obviously, due to the specific nature of the academic disciplines, it is not always necessary to use it. We have not observed any in-depth analysis of the assessment methods used by accredited universities for their compliance with the assessed learning outcomes. We believe that program directors, quality assurance departments, and accreditation bodies need to work on this issue when assessing the implementation of this aspect of the SCL.

11. In the analysis and evaluation of student support services at all IKCA-accredited universities and educational programs, no particular issues were identi-

fied: material and technical equipment is available, information and library resources meet student needs, access to electronic databases is provided, free internet access is available, dormitory space is available for out-of-town students, and extracurricular activities are organized. Each university has effective Student Service Centers, providing up to 20 different services.

However, the EEG reports point to outdated material and technical resources at some universities and in some programs, incomplete information content on websites, and a lack of specialized classrooms.

Conclusion: Thematic analysis shows that the implementation of student-centered learning principles At Kazakhstani universities, this is a process that is at various stages of development. We see that while many universities are striving for this approach, they face a number of challenges that require careful consideration.

- Disjointedness instead of systemicity. The implementation of SCLs often resembles a mosaic: universities add individual, but not always interconnected, elements. For example, they may actively support social policy but overlook the importance of academic mobility or student engagement in research. This creates the feeling that individual steps are being taken, but the overall, coherent picture is not yet in place.

A formal approach. Sometimes what appears to be student-centered learning on paper turns out to be a mere formality in practice. When students' participation in research projects or interactions with practitioners is irregular, this deprives them of the real opportunity to gain valuable experience.

- **Limited opportunities.** Insufficient or complete lack of funding, a lack of international connections, low levels of foreign language proficiency, and poor interaction with the labor market can create a kind of isolation. Without these, it's harder for students to acquire the relevant knowledge and skills needed to be competitive in the future.

At the same time, it is very important to note that there are also positive examples of successful work, which we noted during our analysis of the work of each of the accredited universities.

Recommendations for educational organizations:

- Integrate the SCL into the overall strategy. It's important not just to implement individual elements, but to make the SCL part of the school's mission and vision. This means that all processes—from curricula to extracurricular activities—should be aimed at supporting students.

- More actively introduce additional programs (Minor), micro-qualifications, nano-credits into the content of educational programs, help students find opportunities for informal education within the walls of the university and outside of it (Coursera, MOOC, etc.) to acquire professional competencies that are important for the modern labor market.

- It is necessary to intensify academic mobility by seeking financial resources for this, more clearly explain to students the necessity and advantages of this component of the SCL, strengthen students' research work, improve the material and technical base, and increase information transparency.

We need to create an atmosphere where students feel not only like learners but also active participants in the process. This includes expanding opportunities for participation in research projects, real-world cases, and international programs. We should also conduct more frequent student leadership training sessions, focusing on the most active students.

- Strengthening ties with partners. It's important to establish closer and more ongoing contacts with businesses to ensure that curricula meet employer expectations and that students gain practical experience.

Proposals to the authorized body in the field of higher and postgraduate education (Ministry of Science and Higher Education)

- Consider the possibility of creating grant mechanisms or other financial support for the activities of those universities that demonstrate significant success in implementing SCL.

- Consider the possibility of creating Platforms or events where universities could share their best practices should be created. Continue the effective practice of conducting offline and online training seminars on the implementation of SCL. This would help everyone learn from the examples of leading and successful universities.

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THE IMPORTANCE OF VALUES IN LANGUAGE STUDIES

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Abstract

Language is not merely a neutral instrument for communication; it is a culturally embedded, socially situated, and value-laden phenomenon that reflects and shapes human experience. The present article aims to examine the importance of values in language studies from a philological and interdisciplinary perspective. The primary objective of the study is to conceptualize language as a medium of value realization, transmission, and negotiation within individual, social, and cultural contexts. Drawing upon contemporary linguistic theories—ecological linguistics, axiological linguistics, ethnolinguistics, discourse analysis, and dialogical approaches—this paper demonstrates that values are intrinsic to linguistic meaning, interaction, and education. By synthesizing philosophical, linguistic, and pedagogical research, the article highlights how values are encoded in language structures, communicative practices, and educational discourse, thereby emphasizing their fundamental role in language studies and language teaching. The study contributes to the understanding of language as a moral and cultural practice, underscoring the necessity of integrating value-oriented analysis into modern linguistic research.

Keywords: values, language studies, axiological linguistics, discourse, dialogical interaction, language education

Introduction

In contemporary humanities and social sciences, language is increasingly understood not only as a system of signs or a cognitive mechanism, but as a complex social practice embedded in culture, history, and human interaction. One of the most significant dimensions of this practice is its axiological nature—that is, its inherent connection to values. Values permeate language at multiple levels: lexical meaning, discourse organization, communicative intentions, and pedagogical practices. Consequently, the study of language without reference to values risks reducing linguistic phenomena to formal structures detached from their human significance.

The relevance of values in language studies has become particularly evident in the context of globalization, intercultural communication, and educational transformation. Languages function as carriers of cultural memory, ethical norms, social priorities, and collective identities. Through language, societies articulate what is considered important, desirable, acceptable, or unacceptable. As such, language both reflects existing value systems and actively participates in their formation and transformation.

This article seeks to explore the importance of values in language studies by integrating insights from philosophy, linguistics, and education. Special attention is paid to ecological and dialogical approaches to language, which emphasize interaction, embodiment, and care as fundamental dimensions of communication. By drawing on a wide range of theoretical perspectives and empirical examples, the paper aims to demonstrate that values are not peripheral but central to understanding language as a human phenomenon.

Values as a Philosophical and Linguistic Concept

The concept of value has a long and complex history in philosophy, particularly within axiology. Philosophers such as I. Kant, N. O. Lossky, M. Weber, and J. Ortega y Gasset have emphasized that values are not merely subjective preferences but structured orientations that guide human perception, judgment, and action. Lossky's assertion that meaning and sense constitute an ideal aspect of value highlights the close relationship between value and signification—a relationship that is foundational for linguistic analysis.

From a linguistic perspective, values can be understood as culturally mediated meanings that are encoded and expressed through language. Words do not merely denote objects or actions; they also carry evaluative connotations shaped by historical experience and social norms. Concepts such as *freedom*, *honor*, *justice*, or *responsibility* function as value-laden lexical units whose meanings vary across cultures and discourses.

Importantly, linguistic meaning itself may be considered a form of value. The selection of one expression over another, the framing of an event, or the organization of discourse reflects implicit evaluative choices. Thus, language is inseparable from valuation processes, and linguistic analysis must account for the axiological dimension of meaning.

Axiological Linguistics and Interdisciplinary Approaches

In modern linguistics, the study of values has given rise to several interdisciplinary fields. Axiological linguistics focuses explicitly on the representation and function of values in language and discourse. Ethnolinguistics and ethnolinguoculturology investigate how national and cultural value systems are reflected in linguistic worldviews. Psycholinguistics examines the role of values in language processing and production, while ecolinguistics explores the relationship between language, environment, and ethical responsibility.

These approaches share a common assumption: values are not external to language but are integral to its structure and use. For example, ethnolinguistic research demonstrates that culturally specific values are embedded in idioms, metaphors, and narrative traditions. Political and critical discourse analysis reveals

how language is used to legitimize certain values while marginalizing others. Ecolinguistics, in turn, highlights how linguistic choices influence attitudes toward nature, sustainability, and social responsibility.

By synthesizing these perspectives, language studies can move beyond formal description toward a more holistic understanding of language as a value-oriented practice. This interdisciplinary orientation is particularly important in addressing contemporary challenges such as intercultural misunderstanding, social polarization, and ecological crisis.

Language, Interaction, and Dialogical Values

Recent developments in cognitive science and linguistics emphasize the dialogical and interactive nature of language. From this perspective, language emerges not as an abstract system but as a dynamic process of coordination between individuals engaged in shared activity. Dialogical systems theory conceptualizes communication as a form of joint action in which meaning is co-constructed and values are negotiated in real time.

Within dialogical interaction, values such as cooperation, care, respect, and responsibility play a crucial role. Conversations are not merely exchanges of information; they are sites where social bonds are established, maintained, or challenged. For instance, parent–child interactions, educational dialogues, and professional communication all involve implicit moral orientations that shape linguistic behavior.

The notion of language as a means of caring for others underscores its ethical dimension. Through language, individuals coordinate actions, provide support, and construct shared realities. This understanding aligns with ecological and enactive approaches, which view language as embedded in perception–action systems and social ecosystems. In this sense, values are not abstract ideals but lived orientations enacted through linguistic practice.

Values in Language Education

The role of values is particularly evident in language education. Teaching and learning a language is never a neutral process; it involves choices about content, norms, assessment, and interaction that reflect underlying value systems. Language teachers act not only as instructors of linguistic skills but also as moral agents who shape learners' attitudes, identities, and worldviews.

Research in language pedagogy highlights that classrooms are moral spaces where values such as fairness, inclusivity, respect for diversity, and learner autonomy are continuously enacted. Communicative and project-based approaches emphasize collaboration, mutual understanding, and meaningful interaction, thereby fostering both linguistic competence and ethical awareness.

Moreover, language education plays a critical role in intercultural competence development. By engaging with texts, narratives, and communicative practices from different cultures, learners encounter alternative value systems and learn to negotiate meaning across cultural boundaries. This process contributes to the formation of empathetic, reflective, and socially responsible individuals.

Language, Values, and Society

At the societal level, language functions as a powerful instrument for articulating and contesting values. Public discourse, media communication, and political rhetoric shape collective perceptions of what matters and why. Linguistic analysis of value-laden discourse reveals how social realities are constructed and how power relations are maintained or challenged.

In the digital age, the role of language in expressing personal and collective values has expanded through social media and online communication. Linguistic data from digital platforms provide valuable insights into how values are enacted in everyday language use. Such research demonstrates that values are deeply embedded in patterns of expression, narrative framing, and evaluative language.

Understanding the relationship between language and values is therefore essential for addressing broader social issues, including social cohesion, ethical responsibility, and cultural sustainability.

Conclusion

The analysis presented in this article demonstrates that values occupy a central position in language studies. Language is not merely a technical system of signs but a value-laden practice that reflects and shapes human experience. Values are embedded in linguistic meaning, interaction, education, and social discourse, making them indispensable for a comprehensive understanding of language.

By integrating philosophical, linguistic, and pedagogical perspectives, this study highlights the necessity of value-oriented approaches in modern language research. Recognizing the axiological dimension of language allows scholars and educators to address not only how language functions, but also why it matters. Ultimately, the importance of values in language studies lies in their capacity to connect linguistic analysis with human concerns, ethical responsibility, and cultural understanding.

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PHILOLOGICAL SCIENCES

INTERCULTURALITY: NEW SEARCHES IN GERMAN–TURKISH LITERATURE FROM A LINGUISTIC PERSPECTIVE

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INTERKULTURALITÄT AUS SPRACHLICHER PERSPEKTIVE IN DER DEUTSCH-TÜRKISCHEN LITERATUR: NEUE SUCHBEWEGUNGEN

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Abstract

The process of globalization has transformed literary tradition, experience, and linguistic diversity, thereby paving the way for the emergence of multilayered and multidimensional literary formations. In this context, Turkish migrant literature, which began to become institutionalized in Germany from the 1970s onward, has significantly influenced both German society and the literary public in Germany. Studies aimed at defining the boundaries of interculturality, evaluating the process, and identifying new tendencies on the basis of the theoretical accumulation of literary scholarship are widely recognized in Germany.

The works produced by Turkish authors in Germany in the genres of novels, short stories, poetry, and theater provide important data from the perspective of cultural studies; with regard to the aesthetics of intercultural reception, not only the thematic but also the linguistic dimensions of the texts have become objects of scholarly investigation.

Among authors of Turkish origin living in Germany, different writing practices can be observed: those who think in Turkish and write in Turkish, those who think in Turkish and write in German, and those who think in German and write in German. By employing various genres such as humor, satire, crime fiction, and experimental poetry, these authors have developed original narrative strategies within the context of bilingualism and multilingualism. Turkish women writers, in particular, have introduced new thematic perspectives into German–Turkish literature by making visible the familial and social problems that emerge from women's experiences of migration.

The aim of this study is to analyze the new tendencies of Turkish migrant literature in Germany within an intercultural context and within the framework of German culture and literature. The study also focuses on issues related to language. Throughout the study, the themes of the literary works of authors of Turkish origin are analyzed, with the goal of identifying the main tendencies of their literary activities. Our aim is to analyze the question of national identity through a thematic examination of the works of Turkish migrant writers and poets and to determine the position of Turkish migrant literature within German society and literature.

The scientific novelty of this study lies in examining the contributions of Turkish migrant authors to the German language and literature through a comprehensive analysis of their literary activities in Germany. At the same time, the study analyzes the new aesthetic, thematic, and linguistic tendencies that have emerged in the context of intercultural Turkish migrant literature in Germany. The language choices of migrant authors who produce works in both Turkish and German, the phenomenon of bilingualism, and the function of language in the process of literary construction are examined. Intercultural and comparative analytical methods are employed in the study.

Zusammenfassung

Der Globalisierungsprozess hat literarische Tradition, Erfahrung und sprachliche Vielfalt transformiert und so den Boden für das Entstehen vielschichtiger und vielgestaltiger literarischer Formationen bereitet. In diesem Zusammenhang hat die sich seit den 1970er-Jahren in Deutschland zu institutionalisieren beginnende türkische Migrantenliteratur sowohl die deutsche Gesellschaft als auch die literarische Öffentlichkeit in Deutschland in bemerkenswerter Weise beeinflusst. Auf der Grundlage des theoretischen Erkenntnisstandes der Literaturwissenschaft finden Arbeiten, die darauf abzielen, die Grenzen des Feldes der Interkulturalität zu bestimmen, den Prozess zu bewerten und neue Tendenzen herauszuarbeiten, in Deutschland breite Anerkennung.

Die von türkischen Autorinnen und Autoren in Deutschland in den Gattungen Roman, Erzählung, Lyrik und Theater hervorgebrachten Werke liefern aus der Perspektive der Kulturstudien wichtige Daten; im Hinblick auf die Ästhetik interkultureller Rezeption werden die Texte dabei nicht nur in ihrer inhaltlichen, sondern auch in ihrer sprachlichen Dimension zum Gegenstand der Forschung.

Unter den in Deutschland lebenden Autorinnen und Autoren türkischer Herkunft lassen sich unterschiedliche Schreibpraktiken beobachten: Es gibt solche, die auf Türkisch denken und auf Türkisch schreiben, solche, die auf

Türkisch denken und auf Deutsch schreiben, sowie solche, die auf Deutsch denken und auf Deutsch schreiben. Diese Autorinnen und Autoren haben, indem sie verschiedene Gattungen wie Humor, Satire, Kriminalliteratur und experimentelle Lyrik nutzen, im Kontext von Zwei- und Mehrsprachigkeit eigenständige Erzählstrategien entwickelt. Türkische Autorinnen haben, indem sie insbesondere die familiären und gesellschaftlichen Probleme sichtbar machen, die sich aus der Migrationserfahrung von Frauen ergeben, der deutsch-türkischen Literatur neue thematische Öffnungen erschlossen.

Ziel unserer Studie ist es, die neuen Tendenzen der türkischen Migrantenliteratur in Deutschland im interkulturellen Kontext im Rahmen der deutschen Kultur und Literatur zu analysieren. In der Studie wird darüber hinaus auch auf die Sprachproblematik der Autorinnen und Autoren eingegangen. Im Verlauf der Arbeit werden die Themen der literarischen Werke von Schriftstellerinnen und Schriftstellern türkischer Herkunft analysiert; angestrebt wird die Bestimmung der Haupttendenzen ihrer literarischen Tätigkeit. Unser Ziel besteht hier darin, bei der thematischen Untersuchung der Werke türkischer Migrantenautorinnen und -autoren die Frage der nationalen Identität zu analysieren und die Stellung der türkischen Migrantenliteratur in der deutschen Gesellschaft und Literatur zu bestimmen.

Die wissenschaftliche Neuheit dieser Studie besteht darin, im Rahmen einer Gesamtanalyse der literarischen Aktivitäten türkischer Migrantenautorinnen und -autoren in Deutschland deren Beiträge zur deutschen Sprache und Literatur zu untersuchen. Zugleich zielt die Studie darauf ab, die im interkulturellen Kontext der türkischen Migrantenliteratur in Deutschland hervortretenden neuen ästhetischen, thematischen und sprachlichen Tendenzen zu analysieren. Untersucht werden die Sprachwahl der migrantischen Autorinnen und Autoren, die sowohl auf Türkisch als auch auf Deutsch schreiben, das Phänomen der Zweisprachigkeit sowie die Funktion der Sprache im Prozess literarischer Konstruktion. In der Studie kommen interkulturelle und vergleichende Analysemethoden zur Anwendung.

Schlüsselwörter: Interkulturelle Literatur, deutsch-türkische Literatur, Sprachproblematik
Keywords: Intercultural literature, German–Turkish literature, language issues

Einleitung

Der Globalisierungsprozess hat die Literatur über nationale Grenzen hinausgetragen und sie zu einem Begegnungs- und Interaktionsraum unterschiedlicher kultureller Codes gemacht. Eines der bestimmendsten Elemente dieses Transformationsprozesses ist das Phänomen der Migration. Insbesondere die türkische Migration nach Deutschland nach 1960 führte nicht nur in wirtschaftlichen und gesellschaftlichen Bereichen, sondern auch im Kontext literarischer Produktion zu tiefgreifenden Veränderungen. Die seit den 1970er Jahren in Deutschland einsetzende Institutionalisierung der türkischen Literatur hat sowohl die deutsche Gesellschaft als auch literarische Kreise in bemerkenswerter Weise beeinflusst.

Die literarischen Milieus, Zeitschriften und Schriftstellervereinigungen, die eine Rolle bei der Entwicklung der türkischen Literatur in Europa spielten, haben wesentlich zur Sichtbarkeit dieser Literatur beigetragen. Die von den Autorinnen und Autoren veröffentlichten Werke sowie die von ihnen durch persönliche Initiativen organisierten kulturellen Veranstaltungen machten Literatur zu einem Kommunikations- und Interaktionsmittel zwischen Deutschen und migrantischen Gemeinschaften. Solche Initiativen können als bemerkenswerte kulturelle Ereignisse innerhalb der Migrationsgeschichte zwischen der Türkei und Deutschland bewertet werden.

Die in Deutschland entstandene türkische Literatur bietet aus kulturwissenschaftlicher Perspektive bedeutende akademische Erkenntnisse. Die in Deutschland entwickelte türkische Literatur hat sich im Laufe der Zeit von der Eigenschaft einer „Migrantenliteratur" entfernt und sich in Richtung der Kategorie einer „interkulturellen Literatur" entwickelt. Mit der zunehmenden Etablierung Deutschlands als Lebensraum für türkische Migrantinnen und Migranten veränderten sich auch die literarischen Themen; neue Autorengenerationen rückten die Probleme der Gesellschaft, Identitätsdiskurse sowie Formen kultureller Interaktion in den Mittelpunkt ihrer Werke. In diesem Prozess fallen neue gedankliche Perspektiven und ästhetische Tendenzen auf, die Alternativen zu traditionellen epistemologischen Ansätzen darstellen. Diese Entwicklungen sind in den Werken türkischstämmiger Autorinnen und Autoren in Deutschland deutlich spürbar.

Von der Migrantenliteratur zur „interkulturellen" Literatur

Migration und Migrantendasein zählen nicht nur zu den sozio-demografischen, sondern zugleich zu den zentralen Faktoren, die literarische und kulturelle Systeme prägen. Eine über sechzigjährige Migrationsgeschichte stellt zugleich den Entstehungs- und Entwicklungsprozess einer türkischen Literaturtradition in Deutschland dar. Unter den ersten Generationen türkischer Arbeitsmigranten befanden sich auch Schriftstellerinnen und Schriftsteller. Diese Autoren machten die von ihnen erlebten Schwierigkeiten zum Gegenstand ihrer Werke. In jener Phase war Literatur für sie weniger ein ästhetischer Ausdrucksraum als vielmehr ein Mittel der Zeugenschaft.

Die Autorinnen und Autoren dieser Generation schrieben überwiegend auf Türkisch und thematisierten in ihren Werken das Gefühl der „Vorläufigkeit". In den Texten der ersten Generation dominiert der Zustand des Fremdseins. Türkische Migrantinnen und Migranten, die ihr Heimatland verließen und gezwungen waren, in einem anderen geografischen Raum und kulturellen Umfeld zu leben, waren einer doppelten Erfahrung ausgesetzt: Einerseits lösten sie sich von ihrer eigenen Sprache und ihren kulturellen Wurzeln, andererseits

begegneten sie einer fremden Sprache und Kultur. Da diese beiden Prozesse simultan verliefen, führten sie auf individueller und gesellschaftlicher Ebene zu tiefgreifenden Erschütterungen. Diese Situation kann für bestimmte Individuen und die Gesellschaft, der sie angehören, im Hinblick auf Kultur und Sprache als eine Form von „Abbruch" und im Kontext von Identität als ein „Riss" bezeichnet werden. Entsprechend treten in der Literatur dieser Phase häufig Arbeiterwohnheime, Fabriken, Fremdenfeindlichkeit und soziale Segregation in Erscheinung.

Mit den 1980er Jahren erweiterten in Deutschland geborene und aufgewachsene Autorinnen und Autoren der zweiten Generation den literarischen Horizont, indem sie nicht nur Migrationsprobleme, sondern auch Individualität, modernes Leben, Identitätssuche sowie Übergänge zwischen Sprachen thematisierten. Infolgedessen vertraten Literaturkritiker zunehmend die Auffassung, dass der Begriff „Gastarbeiterliteratur" nicht mehr ausreichend sei (Pazarkaya, 1993, S. 7–8).

Für Autorinnen und Autoren der zweiten Generation, die ihre literarische Laufbahn mit dem Schreiben auf Türkisch begannen, stellte sich die Situation anders dar. Für diese Generation war das Schreiben nicht nur eine Form künstlerischen Ausdrucks, sondern zugleich ein Mittel der Identitätssuche. Zwar wurden Themen wie Entfremdung, Ausgrenzung, kulturelle Inkompatibilität und Missverständnisse häufig behandelt, doch aufgrund der fehlenden Gewichtung ästhetischer und technischer Aspekte der Sprache konnten diese Autorinnen und Autoren weder in Deutschland noch in der Türkei den erwarteten literarischen Erfolg erzielen.

Demgegenüber erreichten einige Autorinnen und Autoren der ersten Generation, die der geschriebenen Sprache besondere Bedeutung beimaßen, die kulturellen Codes ihres Gastlandes berücksichtigten und Ereignisse mit einer beobachtenden Sensibilität aus einer neuen und differenzierten Perspektive betrachteten, trotz des Schreibens auf Türkisch ein gewisses Maß an Anerkennung. Zu dieser Gruppe zählen neben Yüksel Pazarkaya, Güney Dal und Aras Ören auch Schriftsteller wie Habip Bektaş, Gültekin Emre und Hasan Kayıhan.

Dieser Vergleich eröffnet für Schriftstellerinnen, Schriftsteller und Lyriker einen neuen Horizont des Denkens und der Verantwortung. Je sensibler Autorinnen und Autoren in der Sprach- und Themenwahl agieren, desto größer ist die Möglichkeit, literarischen Erfolg zu erzielen. Die von türkischstämmigen Autorinnen und Autoren in Deutschland produzierte Literatur besitzt aus sprachlicher und kultureller Perspektive eine Brückenfunktion zwischen Deutschen und Türken. Dies lässt sich durch die Worte Alois Wierlachers untermauern:

„Interkulturelle Literatur sind Texte, die in den Begegnungszonen zweier oder mehrerer Kulturen entstehen und in deren Zentrum kulturelle Übersetzung steht." (Wierlacher, 2003, S. 25)

Diese Definition Wierlachers lässt sich als treffende Beschreibung der vielschichtigen Struktur der türkischen Literatur in Deutschland verstehen.

In der modernen Epoche nimmt die Zahl junger Autorinnen und Autoren türkischer Herkunft, die Deutsch als künstlerisches Ausdrucksmittel verwenden – wie Osman Engin und Selim Özdoğan – stetig zu. Trotz der poetischen und philosophischen Komplexität der deutschen Sprache haben Schriftstellerinnen und Schriftsteller wie Renan Demirkan, Zehra Çırak, Zafer Şenocak, Feridun Zaimoğlu und Emine Sevgi Özdamar diese Sprache auf literarischem Niveau meisterhaft genutzt und Werke geschaffen, die die Aufmerksamkeit des deutschen Lesepublikums auf sich gezogen haben. Heute gelten sie als anerkannte Stimmen der deutschen Literaturlandschaft.

Die Zahl dieser Autorinnen und Autoren, die sich aktiv am literarischen Leben eines Landes beteiligen, dessen Amtssprache Deutsch ist, nimmt in den letzten Jahren kontinuierlich zu. Obwohl Deutsch nicht ihre Muttersprache ist, stellen ihre ausgeprägten Schreibfähigkeiten, ihre Suche nach neuen Stilformen sowie ihre thematische Vielfalt zentrale Faktoren dar, die ihren literarischen Wert steigern. Diese Autorinnen und Autoren, die sowohl die türkische als auch die deutsche Sprache bewahren, fungieren als literarische Brücke zwischen zwei Kulturen und leisten einen bedeutenden Beitrag zur Vertiefung der gegenseitigen Integration.

Der Sprachgebrauch deutsch-türkischer Autorinnen und Autoren

Sprache stellt das kritischste Element der Migrantenliteratur dar. Der deutsche Philosoph Martin Heidegger, der auf dem von Nietzsche eröffneten Denkweg wandelt und Sprache aus der Perspektive des „Hauses des Seins" betrachtet, argumentiert wie folgt: „Sprache entsteht aus einer Art Auslegung und aus den Bedeutungen oder Markierungen, die diese Auslegung hervorbringt: ‚Wörter fügen sich den Verstehensweisen hinzu.' Wörter und die durch sie bezeichneten Seienden entstammen derselben Sphäre: Während Wörter ursprünglich auf das Seiende verweisen, sind die Seienden selbst ursprünglich bedeutungsgeladen und ermöglichen das Hervortreten der Wörter." (Heidegger, 2014, S. 72)

Bei einer vertieften Betrachtung von Heideggers Sprachverständnis wird deutlich, dass Tradition durch Sprache konstituiert wird. Sprache erscheint hierbei als ein Element, das wir als historischen Hintergrund oder als „Vorverständnis" bezeichnen können und aus dem sich unser Verstehen, Interpretieren sowie viele weitere Aspekte menschlicher Existenz speisen.

Sprache ist nicht lediglich ein Medium, das das Leben widerspiegelt, sondern zugleich ein Faktor, der dem Leben Form verleiht. Dies zeigt sich auch exemplarisch an den Werken türkischstämmiger Autorinnen und Autoren in Deutschland. Die sprachlichen Orientierungen türkischer Autorinnen und Autoren in Deutschland lassen sich in drei Kategorien unterteilen:

1. Auf Türkisch denken und auf Türkisch schreiben
2. Auf Türkisch denken und auf Deutsch schreiben

3. Auf Deutsch denken und auf Deutsch schreiben

Auf Türkisch denken und auf Türkisch schreiben

Für die erste Generation stellt die türkische Sprache sowohl den Träger der Identität als auch des Gedächtnisses dar. Yüksel Pazarkaya fasst diesen Zustand mit den Worten zusammen: „Die Sprache ist die letzte Bastion des Migranten." (Pazarkaya, 1993, S. 11)

Autorinnen und Autoren, die auf Türkisch schreiben, behandeln in ihren Werken vor allem folgende Themen:

- Heimweh,
- Identitätskonflikte,
- Wandel der Familienstruktur,
- sprachliche Barrieren.

Autorinnen und Autoren, die auf Türkisch denken und auf Türkisch schreiben, richten sich in Deutschland vorwiegend an die türkische Diaspora; zugleich leisten sie jedoch einen wesentlichen Beitrag zur Institutionalisierung der türkischen Literatur in Europa.

Auf Türkisch denken und auf Deutsch schreiben

Unter den Autorinnen und Autoren der zweiten Generation ist die Tendenz, auf Türkisch zu denken und auf Deutsch zu schreiben, besonders ausgeprägt. Obwohl die gedankliche Welt türkisch geprägt ist, erfolgt der sprachliche Ausdruck auf Deutsch. Diese Konstellation führt in den Texten zu kultureller und sprachlicher Hybridität. Da das Denken auf Türkisch erfolgt, erscheint das Schreiben auf Deutsch oftmals als eine Art wortwörtliche Übertragung der Gedanken.

Ein besonders eindrückliches Beispiel hierfür findet sich in Emine Sevgi Özdamars auf Deutsch verfasstem Werk *Mutterzunge*. Dort heißt es:„Meine Muttersprache war eine Tür, die sich nach innen öffnete; Deutsch war mein Fenster nach außen." (Özdamar, 1990, S. 9)

Dieser Satz bringt den durch Zweisprachigkeit erzeugten seelischen Zustand mit hoher literarischer Intensität zum Ausdruck. Betrachtet man jedoch die Texte deutscher Literaturkritiker, wird deutlich, dass Autorinnen und Autoren, die auf Türkisch denken und auf Deutsch schreiben, der deutschen Sprache unbewusst zahlreiche Redewendungen und Ausdrucksformen hinzugefügt haben. Im Rahmen der Verleihung deutscher Literatur- und Kunstpreise wird häufig betont, dass es diesen Autorinnen und Autoren gelungen ist, die Lebendigkeit, Anschaulichkeit sowie die reiche und farbige Struktur der türkischen Kultur auf die deutsche Sprache zu übertragen.

Hinsichtlich der Themenwahl ist festzustellen, dass zwischen der ersten und der zweiten Generation kein grundlegender Unterschied besteht. Themen wie Heimatsehnsucht, Sprache, Identität und Fremdheit finden sich auch bei Autorinnen und Autoren der zweiten Generation. Während die erste Generation diese Problematiken überwiegend als kollektive Erfahrung darstellt, individualisiert die zweite Generation diese Fragen und schildert, wie sie sich im inneren Erleben der einzelnen Figuren widerspiegeln. Dies stellt aus literarischer Perspektive eine bedeutende Entwicklung dar.

Auf Deutsch denken und auf Deutsch schreiben

Die dritte Generation umfasst türkischstämmige Autorinnen und Autoren, die in Deutschland ausgebildet wurden und aufgewachsen sind und Deutsch als natürliche Ausdruckssprache verwenden. In den Werken dieser Generation kann das Thema Migration in den Hintergrund treten. Diese Autorinnen und Autoren lassen sich am leichtesten in den Kanon der deutschen Literatur integrieren. Schriftsteller wie Zafer Şenocak, Feridun Zaimoğlu und Hatice Akyün haben den multikulturellen Alltag Deutschlands in unterschiedlichen ästhetischen Formen aufgegriffen. Autoren dieser Kategorie haben auch bedeutende Beiträge zur deutschen Literatur geleistet.

Feridun Zaimoğlu entwickelte mit *Kanak Sprak* eine neue Sprachebene, in der deutsche Umgangssprache mit türkischen Wörtern und Ausdrucksformen verschmilzt. Auf diese Weise entstand eine hybride Sprache, in der sich deutsche und türkische Elemente gegenseitig durchdringen. Kritiker bewerten diese Sprachform als „eine neue literarische Straßensprache" (Lemke, 2001, S. 215). Die von Zaimoğlu entwickelte hybride Sprache, die unter der Bezeichnung *Kanak Sprak* bekannt wurde, stellt eine Mischung aus Deutsch und Türkisch dar und wird in der interkulturellen Sprachforschung als revolutionär angesehen (Lemke, 2001, S. 217).

Feridun Zaimoğlu erläutert die philosophische Grundlage dieser sprachlichen Strategie mit folgenden Worten:„Sprache ist das stärkste Mittel, um Identität neu zu erfinden." (Zaimoğlu, 1995, S. 12)

Diese Aussage tritt in einen direkten Dialog mit Martin Heideggers Verständnis der Sprache als „Haus des Seins". Zaimoğlu errichtet für eine hybride Existenz, die außerhalb etablierter sprachlicher „Häuser" angesiedelt ist, ein neues „Haus" aus den Bausteinen der deutschen und der türkischen Sprache. Dieser Stil hebt die Migrantenliteratur aus dem bloßen Bereich dokumentarischer Zeugnisse heraus und führt sie in einen sprachlich und formal experimentellen ästhetischen Raum über. Zaimoğlus sprachliche Innovation stellt nicht nur einen ästhetischen Bruch dar, sondern zeigt exemplarisch, wie deutsch-türkische Autorinnen und Autoren kollektiv dazu beitragen, den literarischen Mainstream der deutschen Literatur zu transformieren.

Der deutsch-türkische Autor Zafer Şenocak weist in einem Interview darauf hin, dass Sprache nicht allein mit dem Kenntnisstand von Wörtern gleichzusetzen ist. Jede Sprache verfügt über eine ihr eigene Philosophie und Weltanschauung. Autorinnen und Autoren der dritten Generation haben nicht nur die sprachlichen Mechanismen zweier Sprachen übernommen, sondern auch deren historische, philosophische und kulturelle Dimensionen verinnerlicht. Da die deutsche und die türkische Sprache unterschiedlichen Sprachfamilien angehören und keine direkt ineinander übergehenden Sprachsysteme darstellen, eröffnen sie im menschlichen Bewusstsein jeweils eigene Erfahrungs- und Wahrnehmungsräume. In diesem Sinne schaffen

Autorinnen und Autoren, die auf Deutsch denken und auf Deutsch schreiben, sowohl in der türkischen als auch in der deutschen Literatur neue ästhetische und kulturelle Strömungen. Die Sprache dieser Autorengruppe stellt weniger eine Übersetzung dar als vielmehr eine neue Ausdrucksform innerhalb der deutschen Sprache – lebendiger und farbiger.

Bei der Betrachtung der thematischen Ausrichtung von Şenocaks Werken tritt wiederum die Sprachproblematik in den Vordergrund. Fragen von Identität, Zugehörigkeit und dem Zustand des „Fremdseins" werden auf einer philosophischen Ebene behandelt. Die Werke Şenocaks zählen zu den grundlegenden Referenzpunkten der Kulturtheorie. In einem Interview äußert er sich folgendermaßen:

„Beim Lesen meiner Texte sollten Sie sich vermutlich diese Fragen stellen, insbesondere im Rahmen Ihrer wissenschaftlichen Arbeit; ich selbst stelle mir diese Fragen nicht. Ich stelle mir eine völlig andere Frage. Ich frage mich: Was erzähle ich? Welche Art von Geschichte erzähle ich? Ich erzähle hier eine Geschichte – die Geschichte eines kleinen Kindes, das in ein anderes Land kommt. Was tut das Kind? Wie geht das Kind mit dem anderen Land um? Man eröffnet ein Heft, auf dessen einer Seite türkische Wörter stehen, auf der anderen Seite fremde Wörter – in diesem Fall deutsche Wörter. Und dann geschieht Folgendes: Diese fremden Wörter besetzen schließlich einen Teil des Lebensraums, den intimsten Lebensraum, nämlich die Wohnung. Das ist die Geschichte." (https://dergipark.org.tr/en/download/article-file/405298)

Beiträge deutsch-türkischer Autorinnen und Autoren zur deutschen Literatur im interkulturellen Kontext

Als einer der kulturellen Kontaktpunkte Europas hat Deutschland durch Migrationsbewegungen, postkoloniale Debatten, internationale literarische Beziehungen sowie die Erfahrung zweier deutscher Staaten einen reichen interkulturellen Rezeptionsraum hervorgebracht.

Die Werke der ersten Generation weisen überwiegend einen dokumentarischen Charakter auf und spiegeln Migrationserfahrungen wider. Texte wie Bekir Yıldız' *Alman Ekmeği* (*Deutsches Brot*, 1978) thematisieren mit starkem Realismus die Ausbeutung von Arbeitskraft, Entfremdung und kulturelle Konflikte. Die Literatur dieser Phase ästhetisiert Migration vor allem im Rahmen von „Trauma" und „Trennung". Die Sprache ist in der Regel schlicht, direkt und häufig von einer schweren emotionalen Tonlage geprägt.

Ab der zweiten Generation begannen in Deutschland aufgewachsene Autorinnen und Autoren türkischer Herkunft, wie Emine Sevgi Özdamar und Feridun Zaimoğlu, hybride Identitäten und Zweisprachigkeit als ästhetisches Mittel einzusetzen. Özdamars Werk *Mutterzunge* verbindet den Versuch einer Frau, Sprache, Vergangenheit und die durch Migration fragmentierte Identität neu zu konstruieren, mit einer theatralischen Erzählweise. In dieser Generation treten Sprachspiele, multiple Erzähltechniken sowie zeitliche und räumliche Brüche in den Vordergrund. Mit *Kanak Sprak* (1995) schuf Zaimoğlu einen neuen Stil, indem er die deutsche Sprache durch die Integration eines „Subkultur-Jargons" transformierte und ihr einen neuen literarischen Klang verlieh. Dadurch wurde die Migrantenliteratur aus dem Bereich reiner Zeugenschaftstexte herausgelöst und in einen experimentellen ästhetischen Raum überführt.

Deutsch-türkische Autorinnen und Autoren haben die deutsche Literatur insbesondere durch die Thematisierung folgender Aspekte bereichert:

- Diaspora-Erfahrungen,
- kulturelle Konflikte,
- Rassismus und Ausgrenzung,
- Identitätssuche,
- postkoloniale Perspektiven.

Auf diese Weise wurde der gesellschaftliche, ästhetische und thematische Horizont der deutschen Literatur erweitert und zugleich ihre sozialkritische Dimension gestärkt. Darüber hinaus stellt das verstärkte Auftreten weiblicher Stimmen innerhalb der Migrantenliteratur einen bedeutenden ästhetischen Wendepunkt dar. Autorinnen wie Aysel Özakin, Akif Pirinçci und Fatma Aydemir behandeln Themen wie Geschlechterrollen, familiären Druck, kulturelle Konflikte und Emanzipation aus einer feministischen Perspektive. Insbesondere Fatma Aydemirs Roman *Ellbogen* (2017) thematisiert sowohl Migration als auch soziale Klassenprobleme mit einer besonderen Sensibilität. Auf diese Weise entwickelt die deutsch-türkische Literatur eine vielschichtige Ästhetik, die weibliche Erfahrungen ins Zentrum rückt.

Mit der zunehmenden Akzeptanz einer multikulturellen Gesellschaftsstruktur in Deutschland seit den 2000er Jahren ist auch die gesellschaftliche Sichtbarkeit der Migrantenliteratur gestiegen. Die Tatsache, dass Autorinnen und Autoren türkischer Herkunft wie Özdamar, Aydemir oder Zaimoğlu mit renommierten deutschen Literaturpreisen ausgezeichnet wurden, ist ein deutliches Zeichen für die zunehmende Zentralisierung dieser Literatur. Der Gewinn des Georg-Büchner-Preises durch Emine Sevgi Özdamar im Jahr 2022 belegt eindrucksvoll, dass Literatur migrantischer Herkunft inzwischen als konstitutiver Bestandteil der zeitgenössischen deutschen Literatur anerkannt wird.

Die Texte türkischstämmiger Autorinnen und Autoren in Deutschland beschränken sich nicht allein auf die Darstellung von Migrationserfahrungen, sondern erweitern zugleich die kulturellen Grenzen der deutschen Literatur. In der Gegenwart zeigt sich dies unter anderem daran, dass

- türkische Autorinnen und Autoren bei Literaturfestivals in Deutschland ausgezeichnet werden,
- auf Deutsch verfasste Werke Eingang in schulische Curricula finden,
- an Universitäten Lehrveranstaltungen zur „Deutsch-türkischen Literatur" angeboten werden,
- türkische Begriffe wie *Kismet*, *Döner* oder *Yallah* in deutsche Wörterbücher aufgenommen wurden.

In der Fachliteratur wird dieser Einfluss als „kulturelle Bereicherung" bezeichnet (Bauer, 2007, S. 102).

Ursprünglich wurden die Aktivitäten türkischstämmiger Autorinnen und Autoren im deutschen Literaturbetrieb als ein vorübergehendes Phänomen wahrgenommen und unter dem Label „Gastarbeiterliteratur" eingeordnet. Im Laufe der Zeit haben diese literarischen Aktivitäten jedoch tiefgreifende Veränderungen durchlaufen. Über drei Generationen hinweg haben diese Schriftstellerinnen und Schriftsteller durch ihre literarischen Produktionen einen festen Platz im kulturellen Leben Deutschlands eingenommen und sich als integraler Bestandteil der deutschen Literatur etabliert. Parallel zu diesem Entwicklungsprozess sah sich die Öffentlichkeit mit der schwierigen Aufgabe konfrontiert, die Werke „der Anderen", also nicht-deutscher Autorinnen und Autoren, in das monokulturelle Identitätsmodell der deutschen Literatur zu integrieren. Dennoch haben diese Autorinnen und Autoren selbst in den schwierigsten Phasen ihre kreative Arbeit kontinuierlich fortgesetzt.

In diesem Zusammenhang verdienen insbesondere die Auseinandersetzungen türkischstämmiger Schriftstellerinnen und Schriftsteller mit Sprache, kulturellen Referenzen und literarischen Positionierungen besondere Aufmerksamkeit. Eine zukünftige Analyse dieser Literatur unter den Gesichtspunkten von Hybridität, Zweisprachigkeit und Multikulturalität kann wesentlich zu einem tieferen Verständnis der deutschen Literatur sowie der kulturellen Geschichte Deutschlands insgesamt beitragen. Im Ergebnis werden die Werke türkischstämmiger Autorinnen und Autoren heute als unverzichtbarer Bestandteil der zeitgenössischen deutschen Literatur anerkannt.

Schluss

Die türkische Migrantenliteratur, die sich in Deutschland entwickelt hat, bot in ihren Anfangsphasen vor allem begrenzte Repräsentationen, die auf der Zeugenschaft der Migrationserfahrung beruhten. Im Laufe der Zeit wandelte sie sich jedoch zu einer vielschichtigen literarischen Struktur, die Zweisprachigkeit, interkulturelle Interaktion und Identitätsverhandlungen in den Mittelpunkt stellt. Türkischstämmige Autorinnen und Autoren haben sowohl zur deutschen als auch zur türkischen Literatur sichtbare Beiträge geleistet und neue ästhetische Zugänge, Ausdrucksformen sowie thematische Öffnungen entwickelt.

Diese Literatur, die zunächst durch dokumentarische Darstellungen der Lebensbedingungen von Gastarbeiterinnen und Gastarbeitern geprägt war, entwickelte sich im Laufe des Prozesses zu einem experimentellen, pluralistischen und interkulturellen ästhetischen Verständnis. Indem migrantische Autorinnen und Autoren Konzepte wie Identität, Raum, Zwischenpositionen, Sprache und Kultur sowohl auf Türkisch als auch auf Deutsch in originellen Formen verarbeiteten, haben sie nicht nur wesentlich zur Diversifizierung, Pluralisierung und kulturellen Öffnung der zeitgenössischen deutschen Literatur beigetragen, sondern zugleich auch eine neue literarische Ausdrucksweise geschaffen.

Die zunehmende thematische und ästhetische Vielfalt der türkischen Migrantenliteratur hat nicht nur das kulturelle Leben in Deutschland bereichert, sondern darüber hinaus auch die Herausbildung einer multikulturellen gesellschaftlichen Identität unterstützt. Aus diesem Grund wird diese Literatur heute nicht mehr ausschließlich im Rahmen einer „Minderheitenliteratur" betrachtet, sondern als integraler Bestandteil der ganzheitlichen Struktur der zeitgenössischen deutschen Literatur bewertet.

Ziel dieses Beitrags ist es, durch die Untersuchung der sprachlichen Vielfalt, der interkulturellen Ausrichtungen sowie der ästhetischen Entwicklung der türkischen Migrantenliteratur in Deutschland deren Position innerhalb der Literaturwissenschaft sichtbar zu machen und ihren akademischen Wert hervorzuheben.

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PSYCHOLOGICAL SCIENCES

THE IMPACT OF STRESS ON HUMAN REACTIONS AND MANAGEMENT PERSPECTIVES

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Abstract

The rapid development of the modern world and the expansion of the information environment increase the daily psychological burden of people, bringing the relevance of stress to the fore. Stress, as an individual's adaptive response to internal and external influences, shows various manifestations in the physical, emotional and behavioral spheres. People's reaction to stress is related to individual characteristics, perception and assessment abilities. Hans Selye explained stress within the framework of the "general adaptation syndrome" and emphasized both positive and negative aspects of stress. Positive stress plays a stimulating role for individual development and motivation, while negative stress can cause physical, emotional and behavioral problems.

Among the causes of stress, uncontrollable situations, internal and external pressures, tension and changes in relationships occupy a special place. Physical manifestations of stress include headache, fatigue, sleep disturbances, high blood pressure and muscle tension, while psychological manifestations include tension, fear, anxiety, indecisiveness and distraction. Stress coping strategies are presented in two main groups: problem-oriented and emotion-oriented approaches. Problem-oriented approaches focus on eliminating the causes of stress, while emotion-oriented approaches serve to regulate the emotional state of the individual.

Physical activity, relaxation techniques, proper breathing, and effective time management play an important role in stress management. Using social support and creating a balance in lifestyle, as well as taking into account the personality characteristics of the individual, are considered key factors in effectively dealing with stress. The article examines the impact of stress on human reactions, ways to cope with stress, and management perspectives, and provides practical recommendations for improving the quality of life of individuals.

Keywords: stress, reaction, general adaptation syndrome, emotional tension, management, psychological well-being

Introduction

Today's rapidly changing living conditions directly affect a person's psychological balance and make the concept of stress an integral part of daily reality. Increasing social demands, accelerating information flow, and the individual's management of various social roles act as the main factors creating psychological tension.

Stress has always existed in human life, but has become a more widely studied topic in recent years due to globalization and the increasing demands of the modern era. Modern scientific approaches evaluate stress as an adaptive response of the human body to external and internal influences from the environment and explain it as a multifaceted psychological process related to physical, emotional and social factors.

"Stress is an English word that refers to the tension and distress that occurs in a person's mental state. In other words, stress is the mental tension caused by difficult and complex factors that a person encounters in his daily activities and in special circumstances. Stress occurs when the body is exposed to unexpected, sudden, unusual extreme effects and has various manifestations" [2, p.168].

"Selye, who continuously conducted research in the field of stress, defined stress in the 1950s as "a stimulus that causes harm to the organism," and later considered it as "a response in the organism resulting from tension." In 1956, he focused on "non-specific general adaptation symptoms" and suggested that stress is "the organism's demonstration of disease symptoms in the face of harmful factors" [3, p.17].

Hans Selye called stress a "general adaptation syndrome." "Selye considers adaptation to be a fundamental characteristic of life. He shows that there are two ways of living: 1) the active way of struggle, 2) the passive way, of avoiding difficulties, of enduring, of being patient" [6, p.6].

"According to Selye, it has 3 phases: 1) general danger and warning phase - alarm phase; 2) resistance phase; 3) shock phase" [4, p.6].

"Hans Selye also called stress a non-specific defense reaction against any extraordinary impact" [5, p.346].

Stress can positively or negatively affect not only physical and psychological health, but also individuals' daily attitudes and behaviors. Stress should not always be considered a negative factor for the organism. While stressful conditions can hinder an individual's capacity, they can also enable them to realize their potential. Mild levels of stress can be stimulating, motivating, and even prompt action. However, as mentioned above, as the level of stress increases, psychological, physical, and behavioral problems can arise for the individual.

Hans Selye used the concept of stress to encompass both good stress (eustress) and bad stress (distress). According to Selye (1974), an optimal level of stress is necessary for the organism to behave, work, and develop. In other words, beneficial stress is a motivation consisting of the sum of psychological and physical strengths required to overcome obstacles and solve problems. Stress, whether positive or negative, can be observed at every stage of an organism's life. Stress is necessary for personal development and satisfaction.

Stress is a state of difficulty or distress felt as a result of everyday events or pressures in interpersonal relationships. It is defined as an emotional, physical, or cognitive response to environmental pressures, conflicts, tensions, and similar stimuli. The same stressor may not elicit the same emotional responses in everyone. How a stressor is perceived by an individual is crucial. The level of stress experienced by a person can vary depending on how they perceive the stressor. For example, the level of stress experienced by everyone will differ in response to events such as the increasing arms race worldwide, wars, marriage, divorce, taking exams, and running a red light. This is because individuals have different perceptions, thought patterns, interpretations, and belief systems regarding these stressors.

Stress is a state of excessive arousal in both mental and physical dimensions, resulting from an individual's perception of internal and external environmental factors as harmful or threatening. When discussing a stressful situation, it's crucial to focus not so much on the situation itself, but rather on how the individual perceives and interprets it, the defense mechanisms they employ, and their coping skills. A stress response can arise when there's an imbalance between the expectations of the environment and the individual's capabilities. Initially, the individual reacts aggressively to the stress, resisting it, and eventually, the stress can escalate to severe levels, culminating in burnout. The causes of stress include: controllability, pushing boundaries, predictability, pressure, frustration, internal conflict, threat, and change. Stress is a manifestation of adaptation that arises from an action, event, or external factor that creates physical and mental expectations in an individual, varying according to psychological state and individual differences. The stress response is a condition created by the straining and threat to the organism's psychological and physical limits. Stress arises not from what is happening in the environment, but from how the organism reacts to the situation.

Stress can be used interchangeably with concepts such as tension, anxiety, conflict, arousal, severe external conditions, emotional distress, threat to self or security, frustration, etc. Individuals experiencing stress may exhibit physical symptoms such as headaches, digestive problems, high blood pressure, difficulty breathing, and excessive sweating, as well as psychological and behavioral symptoms such as anxiety, anger, tension, unhappiness, irritability, difficulty concentrating, pessimism, indecisiveness, sleep disturbances, and irregular eating habits. A number of symptoms occur before or after the onset of stress. In the literature, stress symptoms are classified in different ways. While some studies group stress symptoms under three main headings-physical, psychological, and behavioral-most studies examine them under the headings of physiological and psychological symptoms. This study also prefers this dual classification.

Physiological symptoms. Physical changes in the human body can sometimes be a result of stress. These changes may also be a symptom of a biological problem not caused by stress, but are generally a reaction of the human body to a stressful event. Common physiological symptoms during stress include: loss of appetite or overeating, weight loss and weakness, chronic fatigue and weakness, insomnia, excessive or irregular sleep, exhaustion, frequent headaches, pain in various parts of the body and joints, shortness of breath, high blood pressure, palpitations, hypersensitivity, emotional changes, tearing, excessive physical pain and suffering, loss of energy, sweating, trembling, allergies, nausea or stomach cramps, hypersensitivity to loud noises, hot or cold flashes.

Psychological symptoms. Psychological symptoms, while not as easily understood as physiological symptoms, are generally quite difficult to notice visually. These symptoms are mostly related to the thought process, the individual's thoughts, and how stress affects this process. Psychological symptoms of stress manifest themselves through the individual's expression of their thoughts to others and their behavior. Common psychological symptoms in stressful situations include: fear and anxiety, excessive nervousness, sensitivity, tension, irritability, incompatibility, feelings of inadequacy, experiencing unwarranted panic, believing everything is meaningless, lack of enjoyment in life, fear of illness or believing one is ill, forgetting tasks, inability to remember events and people, inability to focus on a task for a long time, decreased self-esteem, difficulty making decisions, inability to initiate tasks, generally being pessimistic, anxious, depressed, and focusing on negativity.

Stress management is a very general concept. This general concept is examined in two categories: "direct actions" and "mitigating actions." Direct actions are those aimed at turning negative situations, such as threats and conflicts arising from interaction with the environment, to one's advantage. Examples of direct actions include preparing for danger, exhibiting aggressive behavior, fleeing, or choosing inaction. Mitigating actions, on the other hand, are aimed at relaxing the individual. Through mitigating actions, a person can feel better in emotionally distressing situations and perform their functions more effectively or comfortably.

The essential elements in stress management are: involvement, initiative, willpower, knowledge, and common sense.

A person's coping mechanisms in stressful situations can be divided into two groups: "active and problem-oriented" and "passive and defensive". These methods are considered "adequate" or "functional" if they can reduce or even eliminate stress. Conversely, if they cause more stress, they are called "inadequate" or "dysfunctional" mechanisms. Inadequate methods can also be grouped into two categories:

- ✓ Inappropriate behaviors include: resorting to alcohol and substances, avoidance behaviors, aggression, withdrawal, depression, suicidal tendencies, and other mental health problems.
- ✓ Behaviors aimed at self-deception: various defense mechanisms such as rationalization, repression, denial, and projection.

The adequate methods can be examined in three groups:

✓ Methods focused on the body: various relaxation techniques such as deep muscle relaxation, meditation, and yoga, breathing exercises, proper nutrition, and aerobic gymnastics.

✓ Methods for dealing with emotions and thoughts: making it a habit to approach life like a scientist. Interpreting stressors as opportunities to test abilities rather than threats, learning to test irrational beliefs, being able to share emotions with others, and expressing emotions openly and appropriately.

✓ Situation-specific approaches: improving communication skills, managing time effectively, leveraging social support, developing assertive behaviors, and improving problem-solving skills.

There are two main coping mechanisms that individuals use when faced with stressful or difficult situations: problem-focused and emotion-focused. "Problem-focused coping" involves the individual identifying the stressful situation and taking effective steps to overcome it. "Emotion-focused coping", on the other hand, involves the individual turning to others and seeking social support. This type of coping strategy includes ignoring the existing situation and avoiding any interaction aimed at resolving the problem.

The stress response is not something that needs to be completely blocked or eliminated. To a certain extent, stress is a mental, physical, and emotional response that increases a person's drive and resilience, makes it easier to cope with difficulties, and provides resistance. Most individuals have achieved success through a drive fueled by stress in their lives. This is because stress, when at the appropriate level and quality, is a stimulus that develops, motivates, strengthens, and provides experience to the individual. It is suggested that there are three main goals in coping with stress. These goals can be expressed as follows:

• In the short term: learning all the methods and rules to follow in order to effectively cope with stress.

• In the medium term: to create a lifestyle that minimizes the negative effects of stress by learning about its causes and symptoms, and recognizing its potential impact in advance. To be able to utilize the positive aspects of stress where appropriate.

• In the long term: being able to live a peaceful, healthy, organized, and productive life where stress is managed.

The following are individual strategies that should be used effectively to cope with stress:

Changing personality traits, taking control of life, incorporating humor and jokes into daily life, avoiding comparisons with others, utilizing the advantages and positive aspects of stress and stress responses, and learning to live with chronic and intractable stress.

"The best proven tools for preventing stress are: the ability to properly plan your time (for example, preparing a schedule of priority issues, analyzing the time spent on various types of activities, using time rationally, finding additional time resources); engaging in sports and physical activities; mastering exercise skills, self-hypnosis techniques, and other relaxation methods" [1, p.122].

One of the factors that makes it difficult to cope with stress is personality traits. People who are overly sensitive, selfish, rigid, anxious, pessimistic, introverted, reactive, aggressive, anxious, ambitious, quick-tempered, and have a predominance of hostile feelings have a very difficult time coping with stress.

Conclusion

Whether stress benefits or harms the individual largely depends on the individual. The stress response can be a burden that threatens a person psychologically and physiologically, but it can also be a source of energy, helping them cope with life's difficulties. When an individual experiences stress, the body automatically reacts: heart rate increases, sweating intensifies, breathing quickens, and muscle tension increases. In short, the body goes into a state of alert. It is possible to cope with this state of alertness, that is, with stress. A large part of the stress an individual experiences is not in the event or situation itself, but in the meaning they attach to it. Stress management requires awareness of the changes in the body and mind. Furthermore, avoiding or minimizing the use of thought patterns that lead to stress will be beneficial. Proper breathing can send a message to the body that everything is alright. In addition, one of the most important methods of coping with stress is regular exercise. Because regular exercise relaxes muscles, regulates breathing, and helps with healthier thinking and feeling. Leading a passive and inactive life reinforces stress. Another point to consider is regular and sufficient sleep and healthy eating. Lack of sleep or irregular sleep and unhealthy eating can create a vicious cycle, feeding off each other and causing more stress. Effective time management is also an effective method for coping with stress. Time management generally consists of three steps: planning, implementation, and evaluation. Another stress management technique is eliminating uncertainty. Uncertainty is one of the most significant sources of stress. Reducing uncertainties in life and controlling the controllable aspects will reduce stress.

In summary, the following points are recommended for stress management:

Being able to say "no," not being overly perfectionistic, sharing, not hoarding, having hoarding habits, making time for yourself, prioritizing sports and healthy eating, taking good care of your body, learning breathing exercises and relaxation techniques, spending time with loved ones, not neglecting rest, being organized, and not procrastinating.

For this reason, recognizing stress, properly assessing it, and developing management skills is considered one of the key conditions for maintaining an individual's psychological well-being and improving their quality of life.

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SOCIAL SCIENCES

COMPLEX ADAPTIVE SYSTEMS AND PUBLIC ADMINISTRATION: GOVERNING IN AN ERA OF COMPLEXITY

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Abstract

Contemporary governments operate in environments characterized by volatility, uncertainty, interdependence, and rapid change, exposing the limitations of traditional public administration models grounded in hierarchy, linear causality, and centralized control. This article advances the argument that public administration is best understood as a Complex Adaptive System (CAS). Drawing on complexity science and integrating insights from administrative theory, governance networks, resilience studies, and adaptive management, the paper examines how public sector institutions, policymaking processes, and governance arrangements evolve through nonlinearity, emergence, self-organization, feedback, and adaptation. It demonstrates that administrative behavior and policy outcomes arise from dynamic interactions among diverse actors across multiple levels and sectors rather than from top-down design alone. By reframing public administration as an adaptive and learning-oriented system, the article provides a more realistic framework for understanding governance under conditions of uncertainty, crisis, and transformation. The CAS perspective offers important implications for administrative leadership, institutional design, innovation, accountability, and crisis governance, while also acknowledging the normative and practical challenges of applying complexity theory in democratic governance contexts.

Keywords: Complex Adaptive Systems; Public Administration; Complexity Theory; Governance Networks; Adaptive Governance; Emergence; Self-Organization

1. Introduction

Public administration in the twenty-first century is confronted by an unprecedented level of complexity arising from globalization, technological transformation, demographic shifts, environmental pressures, and geopolitical volatility. Traditional administrative paradigms—rooted in hierarchical control, rational planning, and linear causality—offer limited explanatory or practical power for governing systems characterized by interdependence, nonlinear interactions, and rapid, unpredictable change. Consequently, public administration scholars and practitioners increasingly recognize the need for theoretical and operational frameworks that reflect the dynamic and adaptive nature of contemporary governance environments (Weber, 1978; Simon, 1985; Lindblom, 1959).

Historically, public administration evolved through distinct paradigmatic shifts, each seeking to address emerging societal challenges. Classical Weberian bureaucracy emphasized rules, hierarchy, and rational-legal authority as mechanisms for ensuring efficiency, predictability, and impartiality. This model provided an institutional foundation for modern states but rested on assumptions of stability and controllability. The mid-twentieth century saw the emergence of human relations theory, behavioralism, and incrementalism, which attempted to reconcile bureaucratic structures with human decision-making limitations and the realities of political negotiation (Klijn & Koppenjan, 2016).

Later, the New Public Management (NPM) movement sought to import private-sector methods—competition, performance metrics, contracting-out—into the public sphere to enhance efficiency and responsiveness. While NPM introduced valuable innovations, its market-driven logic often fragmented public services and overlooked the inter-dependencies across sectors and jurisdictions. The subsequent rise of the New Public Governance (NPG) paradigm emphasized collaboration, networks, and co-production, reflecting a shift away from state-centric models toward multi-actor governance arrangements (Hood, 1991; Pollitt & Bouckaert, 2017).

These reform movements did not fully account for the inherent unpredictability and emergent properties of modern governance challenges. Issues such as climate adaptation, digital misinformation, autonomous technologies, pandemic response, supply-chain fragility, and financial contagion cannot be effectively managed through linear, reductionist frameworks. These problems exhibit the hallmarks of complexity: nonlinearity, uncertainty, interdependence, path dependence, and adaptive behavior among actors operating at multiple scales (Sterman, 2000; Room, 2011).

Complex Adaptive Systems (CAS) theory offers a promising alternative lens for understanding and governing these multifaceted challenges. Originating from fields such as biology, ecology, computer science, and evolutionary theory, *CAS* emphasizes how diverse agents interact, learn, and adapt within dynamic systems. Key principles—emergence, self-organization, feedback loops, distributed control, and co-evolution—provide powerful conceptual tools for analyzing how public administration systems behave and transform. Reconciling *CAS* concepts with public administration is not merely metaphorical; it reflects the empirical reality of how modern governance operates. Administrative organizations are ecosystems

of interdependent units and professionals whose behaviors shape—and are shaped by—often unpredictable environmental forces. Policy processes unfold through nonlinear interactions among stakeholders, interest groups, and institutions, producing outcomes that cannot be fully predicted or centrally engineered. Governance networks embody distributed authority, collaborative problem-solving, and inter-organizational learning, all of which reflect *CAS* dynamics (Rhodes, 1997; Kickert et al., 1997; Osborne, 2010)

By reframing public administration as a complex adaptive system, this paper offers a deeper analysis of how complexity science enriches our understanding of administrative behavior, policymaking, institutional design, crisis management, accountability, and public sector innovation (Baumgartner & Jones, 1993).

2. Theoretical Foundations of Complex Adaptive Systems

Complex Adaptive Systems (CAS) theory provides a powerful interdisciplinary framework for understanding systems characterized by multiple interacting components, nonlinear dynamics, and continual adaptation. Rather than viewing systems as mechanistic structures governed by linear cause–effect relationships, *CAS* conceptualizes them as evolving, self-organizing entities whose behavior emerges from interactions among heterogeneous agents operating under conditions of uncertainty.

2.1 Intellectual Origins of Complexity and CAS Theory

The foundations of *CAS theory* lie in a convergence of ideas drawn from general systems theory, cybernetics, evolutionary biology, thermodynamics, and later computational modeling. Early systems theorists, most notably Ludwig von Bertalanffy, challenged reductionist scientific approaches by emphasizing that systems must be understood holistically, as organized wholes whose properties cannot be deduced from isolated parts. This insight was foundational for later complexity thinking, as it highlighted interdependence, interaction, and systemic behavior.

Cybernetics, pioneered by Norbert Wiener, further advanced these ideas by focusing on communication, control, and feedback within systems (Prigogine & Stengers, 1884). Feedback mechanisms—both reinforcing and balancing—were shown to be central to how systems maintain stability or undergo transformation. These insights proved especially influential for organizational and administrative theory, where feedback loops shape decision-making, performance, and learning processes (Comfort, 1999).

Evolutionary biology provided another critical intellectual pillar. Darwinian principles of variation, selection, and adaptation demonstrated how complex order can arise without centralized design. In *CAS*, agents adapt their behavior based on experience and environmental signals, leading to evolutionary dynamics that reshape system structures over time. This evolutionary perspective later influenced institutional theories that emphasize gradual change, path dependence, and co-evolution between organizations and their environments (Ostrom, 2000).

Thermodynamics, particularly the work of Ilya Prigogine on dissipative structures, further challenged equilibrium-based models by showing that systems far from equilibrium can generate new forms of order. Applied to social and administrative systems, this insight implies that instability, crises, and shocks are not merely disruptions but potential sources of innovation and transformation (Ansell & Bartenberger, 2016; Torfing, 2019; Prigogine & Stengers, 1984). Their work underscored that complexity is not randomness but structured unpredictability—a crucial distinction for governance and policy analysis.

2.2 Core Principles of Complex Adaptive Systems

CAS theory is defined by a set of interrelated principles that collectively challenge linear, deterministic models of governance and administration (Rhodes, 1997; Dunlop et al., 2020). These foundational *CAS* concepts are particularly relevant for public administration:

- *Nonlinearity*: In complex systems, relationships between cause and effect are nonlinear. Small interventions can trigger large-scale consequences, while substantial efforts may yield limited impact. This principle undermines assumptions of proportionality embedded in rational planning and performance management frameworks. In public administration, nonlinearity explains why policies often generate unintended consequences and why reforms rarely unfold as designed.
- ***Emergence*:** Emergence refers to system-level properties or patterns that arise from interactions among agents rather than from centralized control. Organizational culture, informal norms, policy outcomes, and governance routines are emergent phenomena. They cannot be fully predicted or engineered but evolve through practice and interaction. Emergence is particularly salient in public administration, where formal rules coexist with informal practices that shape actual behavior.
- *Feedback Loops*: Feedback mechanisms play a central role in shaping system dynamics. Reinforcing feedback amplifies trends—such as escalating crises or rapid diffusion of innovations—while balancing feedback dampens change and promotes stability. Policy failures often result from neglecting feedback effects, such as delayed behavioral responses or adaptive reactions by stakeholders.
- *Self-Organization*: *CAS* exhibit the capacity to generate internal order without external direction. Self-organization occurs when agents adjust their behavior locally in response to constraints and opportunities, producing coordinated outcomes at the system level. In governance contexts, self-organization is evident in informal networks, collaborative problem-solving, and frontline discretion.
- ***Adaptation and Learning*:** Agents within *CAS* continuously learn from experience and modify their strategies accordingly. This adaptive behavior leads to co-evolution between systems and their environments.

In public administration, adaptation manifests through organizational learning, policy experimentation, and institutional reform driven by changing social, technological, and political conditions.

- *Distributed Control and Polycentricity:* Control in *CAS* is distributed rather than centralized. No single actor possesses complete information or authority over the system. This principle aligns closely with polycentric governance arrangements, where multiple decision centers operate autonomously yet interdependently. Distributed control challenges hierarchical command-and-control models and supports collaborative and networked governance approaches.

Together, these principles provide a conceptual framework for understanding why public administration systems resist full control, generate unexpected outcomes, and require adaptive rather than deterministic forms of governance (Boin et al., 2017; Duit et al., 2010).

2.3 Complexity and the Evolution of Public Administration Theory

The increasing recognition of complexity has reshaped public administration theory over the past four decades. Several intellectual currents paved the way for complexity-informed governance.

- *From Hierarchy to Networks*: Traditional hierarchical models emphasized control, uniformity, and predictability. However, governance networks emerged as collaborative arrangements among public, private, and civil society actors. Some scholars such as Rhodes (1997) and Kickert et al. (1997) highlighted the limitations of top-down control and the need for negotiated problem-solving.
- ***From Linear Planning to Adaptive Management*:** Policy studies increasingly acknowledged that rational planning fails under conditions of uncertainty. Adaptive management—rooted in ecology and applied to policy—promotes iterative learning, experimentation, and adjustment. Complexity science provided theoretical support for these adaptive practices.
- ***From Command-and-Control to Co-production*:**

Governments now recognize citizens, communities, and stakeholders as co-producers of public value. This shift reflects distributed control and the interdependence characteristic of *CAS.*

- *From Stability to Resilience*: Resilience theory, emerging from ecology, emphasizes the capacity of systems to absorb shocks and reorganize. As public administration confronts crises such as pandemics, natural disasters, and cyberattacks, resilience has become a central governance objective.
- ***From Bureaucratic to Post-Bureaucratic Models*:** Complexity aligns with post-bureaucratic governance characterized by flexibility, decentralization, and boundary spanning. This evolution challenges assumptions of central steering and replace them with facilitative leadership and network coordination.

Rather than seeking optimal solutions, these approaches prioritize robustness, responsiveness, and the capacity to cope with uncertainty—core concerns of *CAS.*

2.4 Why CAS Is Particularly Suited to Contemporary Governance

Contemporary governance environments are characterized by volatility, uncertainty, complexity, and ambiguity. Challenges such as climate change, pandemics, digital transformation, migration, and cybersecurity are not merely complicated but genuinely complex (Room, 2011). They involve multiple interacting systems, contested values, and rapidly evolving conditions. *CAS theory* is particularly well suited to these contexts because it: recognizes uncertainty as an inherent feature rather than a temporary information deficit; explains why control must be partial, indirect, and adaptive; emphasizes learning, experimentation, and feedback; accounts for emergent outcomes and unintended consequences; ad aligns with multi-level, multi-actor governance arrangements (Ostrom, 2010; Torfing, 2019).

By reframing public administration as a complex adaptive system, *CAS theory* moves the field beyond mechanistic metaphors toward a more realistic understanding of how governance actually functions.

3. Public Administration as a Complex Adaptive System

Conceptualizing public administration as a *Complex Adaptive System (CAS)* represents a fundamental departure from mechanistic, hierarchical, and linear models of governance. Rather than viewing government as a centralized apparatus capable of steering society through command-and-control mechanisms, the *CAS* perspective understands public administration as an evolving system composed of multiple, interdependent agents whose interactions generate emergent patterns of governance. Administrative institutions, policy processes, and governance networks are thus not static structures but dynamic systems characterized by adaptation, learning, feedback, and nonlinearity (Rhodes, 1997; Kickert et al., 1997; Osborne, 2010).

Public administration systems meet all essential criteria of *CAS:* first*,* they comprise diverse actors with heterogeneous preferences and capabilities; second, they operate under conditions of uncertainty and bounded rationality; third, they adapt to internal and external feedback; and fourth, they produce outcomes that cannot be fully predicted or centrally controlled. Viewing public administration through a *CAS* lens therefore offers a more realistic account of how governance actually functions in complex, pluralistic, and rapidly changing societies (Room, 2011; Hood, 1991).

3.1 Policymaking as a Complex Adaptive Process

Traditional policy models often depict policymaking as a linear cycle progressing from problem identification to formulation, implementation, and evaluation. While analytically convenient, this representation obscures the complex, adaptive, and emergent nature of real-world policy processes. From a

CAS perspective, policymaking is a dynamic system of interactions among multiple actors operating across institutional, sectoral, and temporal boundaries. Policy systems exhibit nonlinearity, meaning that policy change is rarely incremental or proportional. Long periods of stability may be punctuated by sudden shifts triggered by relatively minor events, framing changes, or institutional realignments. Theories such as punctuated equilibrium and multiple streams implicitly reflect *CAS* dynamics by emphasizing feedback, coupling, and sudden realignment rather than steady progress (Sterman, 2000; Room, 2011).

Policymaking also involves co-evolution between policy actors and their environments. Governments respond to societal demands, technological innovation, economic shocks, and global pressures, while simultaneously reshaping those environments through regulation, investment, and discourse. Policy instruments and institutions adapt over time through learning, diffusion, and experimentation, often in response to failure rather than success (Baumgartner & Jones, 1993).

Importantly, policy outcomes emerge from interaction rather than design. Negotiation, interpretation, coalition-building, and informal practices shape how policies are enacted and experienced. Implementation is not a downstream phase but an integral part of policy adaptation, as actors reinterpret goals and adjust strategies in response to feedback. This perspective challenges the assumption that better analysis or planning alone can ensure effective policy outcomes (Dunlop et al., 2020; Duit et al., 2010).

Viewing policymaking as a *CAS* shifts emphasis from optimization to adaptability. Rather than seeking optimal solutions, policymakers must cultivate learning capacities, iterative adjustment, and responsiveness to evolving conditions. Policy success, in this view, depends less on predictive accuracy and more on the system's ability to sense change, absorb shocks, and reorganize (Baumgartner & Jones, 1993).

3.2 Governance Networks as Complex Adaptive Systems

Governance networks represent one of the clearest empirical manifestations of complexity in public administration. Contemporary governance increasingly relies on networks of public agencies, private firms, nonprofit organizations, community groups, and international actors. These networks operate through negotiation, trust, and mutual dependence rather than through hierarchical authority (Kickert et al., 1997; Osborne, 2010).

From a *CAS* perspective, governance networks are adaptive systems characterized by distributed control, interdependence, and self-organization. No single actor possesses sufficient authority, resources, or knowledge to address complex public problems independently. Instead, collective action emerges through interaction, coordination, and learning among network participants.

Networks evolve over time as actors enter or exit, relationships deepen or erode, and shared understandings develop. Crisis situations often reveal the adaptive strengths of networked governance, as informal ties and decentralized decision-making enable rapid response. Conversely, rigid hierarchical control can hinder adaptation by slowing information flows and suppressing local initiative.

Diversity within governance networks enhances resilience. Multiple perspectives, overlapping capacities, and redundant resources enable systems to cope with uncertainty and disruption. *CAS* theory thus provides a strong theoretical justification for collaborative governance, co-production, and polycentric institutional arrangements (Osborne, 2010).

However, networks also generate coordination challenges, accountability dilemmas, and power asymmetries. *CAS theory* does not romanticize networks but explains why governance outcomes are contingent, emergent, and shaped by interaction rather than design.

3.3 Public Sector Innovation in Complex Adaptive Systems

Innovation in public administration is often portrayed as the result of strategic leadership or centralized reform initiatives. In practice, however, innovation typically emerges from experimentation at the margins of the system. Local units, frontline workers, and inter-organizational collaborations frequently develop novel solutions in response to immediate problems (Ansell & Bartenberger, 2016; Torfing, 2019).

CAS theory explains why innovation is inherently decentralized and emergent. In complex systems, experimentation generates variation, feedback enables selection, and successful practices diffuse through networks. Innovation is therefore evolutionary rather than planned, and failure plays a crucial role in learning and adaptation.

Complexity-informed governance emphasizes "safe-to-fail" experimentation rather than "fail-safe" planning. Small-scale pilots, iterative refinement, and rapid feedback allow systems to learn without catastrophic risk. This approach contrasts with traditional public sector risk aversion, which often suppresses experimentation and locks systems into suboptimal paths.

Public sector innovation capacity thus depends on institutional conditions that support learning, trust, and adaptability. These include flexible rules, supportive leadership, cross-boundary collaboration, and mechanisms for knowledge sharing. *CAS theory* provides a coherent framework for understanding how such conditions enable innovation in complex governance environments (Torfing, 2019).

4. Implications of CAS for Public Administration Practice

Reconceptualizing public administration as a *Complex Adaptive System (CAS)* has profound implications for how public institutions are designed, led, managed, and evaluated. Traditional administrative practice has been dominated by assumptions of predictability, control, and linear causality. In contrast, a *CAS* perspective recognizes uncertainty, emergence, and adaptation as enduring features of governance. This

shift requires not incremental managerial adjustments but a fundamental reorientation of public administration practice toward adaptability, learning, and systemic stewardship.

4.1 Adaptive Leadership

CAS theory transforms the role of leadership in public administration. Rather than emphasizing command, control, and directive authority, complexity-informed leadership prioritizes facilitation, sensemaking, and the creation of enabling conditions for adaptive behavior.

In complex systems, leaders cannot fully predict outcomes or control system dynamics. Instead, their primary role is to guide attention, frame problems, foster shared understanding, and support self-organization. Adaptive leadership involves helping organizations and networks interpret ambiguous situations, navigate competing values, and respond constructively to uncertainty (Kickert et al., 1997; Osborne, 2010). Essential features of *CAS-informed* leadership include:

- ***Sensemaking and framing*:** Leaders help actors interpret complex environments, recognize emerging patterns, and align action around shared narratives.
- ***Enabling self-organization*:** Rather than prescribing detailed solutions, leaders create space for experimentation, collaboration, and bottom-up problem-solving.
- *Managing tensions*: Complex systems involve persistent trade-offs—such as efficiency versus equity or stability versus innovation—which leaders must manage rather than resolve permanently.
- ***Distributed authority*:** Leadership is exercised across multiple levels and actors, recognizing that expertise and initiative often reside at the periphery of the system.
- ***Tolerance for uncertainty and failure*:** Adaptive leaders accept that failure is an inevitable component of learning in complex systems and protect experimental initiatives from premature political or bureaucratic closure.

This redefinition of leadership shifts public managers from being controllers of behavior to stewards of system capacity, responsible for nurturing relationships, trust, and adaptive potential (Dunlop et al., 2020; Gell-Mann, 1994; Bovens, 2007).

4.2 Institutional Design for Complexity

Institutions designed for stable environments and routine tasks struggle under conditions of complexity. *CAS theory* therefore implies the need for institutional arrangements that emphasize flexibility, modularity, and responsiveness rather than rigidity and uniformity (Room, 2019).

Complexity-informed institutional design departs from one-size-fits-all bureaucratic structures and instead promotes adaptive architectures that can evolve over time. Such designs recognize that different problems require different forms of coordination and that institutional diversity enhances system resilience. Core design principles include:

- ***Flexible and modular structures*:** Organizations should be capable of reconfiguring teams, processes, and partnerships in response to emerging challenges.
- ***Decentralized decision-making*:** Authority should be pushed closer to the point of action, enabling local units to respond to contextual variation.
- ***Boundary-spanning mechanisms*:** Inter-agency task forces, cross-sector partnerships, and collaborative platforms facilitate coordination across organizational silos.
- ***Iterative policy design*:** Policies should be piloted, evaluated, and refined through cycles of learning rather than implemented as fixed blueprints.
- ***Embedded feedback systems*:** Continuous monitoring and feedback enable institutions to detect unintended consequences and adapt accordingly.

From a *CAS* perspective, institutions are not static rule systems but evolving governance arrangements that must balance stability with adaptability (Torfing, 2019; Comfort, 1999; Holland, 1992).

4.3 Learning, Knowledge, and Information Systems

Learning is a central mechanism through which complex adaptive systems evolve. *CAS theory* implies that effective public administration depends less on comprehensive ex ante planning and more on continuous learning, experimentation, and knowledge exchange (von Bertalanffy, 1968; Kauffman, 1993)

Traditional public administration often treats learning as episodic—occurring through formal evaluations or audits. In contrast, *CAS-oriented* practice embeds learning into everyday routines, decision processes, and inter-organizational interactions. Major implications include:

- ***Multi-level learning*:** Public organizations must support single-loop learning (improving actions), double-loop learning (questioning assumptions), and triple-loop learning (rethinking governance structures).
- Communities of practice: Informal professional networks facilitate peer learning, knowledge diffusion, and innovation across organizational boundaries.
- ***Real-time feedback*:** Digital tools, data analytics, and participatory feedback mechanisms enhance the system's capacity to sense and respond to change.
- ***Learning from failure*:** Failure is treated as diagnostic information rather than as evidence of incompetence, provided risks are managed responsibly.
- ***Co-production of knowledge*:** Citizens, service users, and frontline workers contribute experiential knowledge essential for adaptive governance.

CAS theory thus reframes public administration as a learning system rather than a rule-enforcing apparatus.

4.4 Accountability in Complex Systems

One of the most challenging implications of *CAS* for public administration practice concerns accountability. Traditional accountability models assume clear lines of authority, stable goals, and direct

control—assumptions that rarely hold in complex, networked governance environments.

CAS-oriented governance involves multiple actors, overlapping responsibilities, and emergent outcomes, producing what scholars describe as *"multiple accountabilities disorder."* In such contexts, rigid accountability mechanisms can undermine adaptability by discouraging experimentation and collaboration. (Bovens, 2007; Dubnick & Frederickson, 2011). Complexity-informed accountability emphasizes:

- *Adaptive accountability*: Accountability mechanisms that evolve with changing goals, contexts, and partnerships.
- *Relational and dialogic accountability*: Ongoing dialogue, transparency, and mutual monitoring among actors rather than purely hierarchical oversight.
- *Shared accountability in networks*: Collective responsibility for outcomes in collaborative governance arrangements.
- *Outcome-oriented accountability*: Focus on learning and improvement rather than compliance alone.
- ***Democratic anchoring*:** Ensuring that adaptive governance remains aligned with public values, legitimacy, and political oversight.

Rather than eliminating accountability, *CAS theory* calls for accountability systems that are compatible with uncertainty, learning, and shared authority (Bovens, 2007; Dubnick & Frederickson, 2011).

4.5 Crisis Governance and System Resilience

Crises provide a critical test of public administration systems and vividly illustrate *CAS* dynamics. Pandemics, natural disasters, financial crises, and cyber threats expose the limits of centralized control and linear planning. *CAS theory* offers a powerful framework for understanding and improving crisis governance by emphasizing resilience—the capacity of systems to absorb shocks, adapt, and reorganize without losing core functions (Holling, 1973; Duit et al., 2010). Major implications are as follows:

- ***Decentralized response capacity*:** Local units and frontline actors often respond faster and more effectively than centralized authorities.
- *Network activation*: Informal and cross-sector networks play a crucial role in mobilizing resources and information during crises.
- ***Diversity and redundancy*:** Multiple pathways, overlapping capabilities, and institutional diversity enhance system robustness.
- *Continuous preparedness*: Resilience is built through ongoing learning, simulation, and adaptation rather than static contingency plans.
- *Post-crisis learning*: Crises should be treated as opportunities for institutional learning and transformation rather than temporary disruptions.

CAS theory thus reframes crises not as anomalies but as normal stressors in complex governance systems, requiring adaptive rather than purely preventive strategies.

5. Challenges and Critiques of Applying Complex Adaptive Systems to Public Administration

Despite its growing influence and explanatory power, the application of *CAS theory* to public administration is not without significant challenges and critiques. While *CAS* offers a compelling alternative to linear and mechanistic governance models, scholars caution against uncritical adoption, conceptual ambiguity, and practical misapplication. This section critically examines the main theoretical, methodological, normative, and practical limitations of *CAS* in public administration, while clarifying how these challenges can be constructively addressed.

5.1 Conceptual Ambiguity and Metaphorical Overreach

One of the most frequently cited critiques of *CAS* in public administration is its conceptual ambiguity. Critics argue that complexity concepts—such as emergence, self-organization, adaptation, and nonlinearity—are often employed metaphorically rather than analytically. When used loosely, *CAS* risks becoming an attractive but imprecise vocabulary rather than a rigorous theoretical framework (Sterman, 2000; Room, 2011).

In public administration scholarship, complexity is sometimes invoked to describe almost any situation involving uncertainty or multiple actors. This broad usage can dilute analytical clarity and make it difficult to distinguish *CAS-informed* analysis from existing institutional, behavioral, or network theories. Reviewers and practitioners may question whether *CAS* offers genuinely new insights or simply repackages established ideas under a different label.

Furthermore, the translation of concepts from natural sciences to social systems raises epistemological concerns. Unlike biological or computational systems, public administration involves intentional actors, power relations, values, and political contestation. Treating administrative systems as if they were purely self-organizing may obscure agency, conflict, and strategic behavior.

5.2 Limited Predictive Capacity and Policy Uncertainty

Another major critique concerns the limited predictive capacity of *CAS theory*. Policymakers and administrators often require forecasts, targets, and performance indicators to justify decisions and allocate resources. *CAS,* by contrast, emphasizes uncertainty, path dependence, and emergent outcomes, offering explanation rather than precise prediction. This limitation creates tension between complexity-informed governance and the political demand for certainty, control, and measurable results. Critics argue that *CAS* may be analytically insightful but practically unsatisfying, especially in high-stakes policy areas such as budgeting, national security, or infrastructure planning. Moreover, if outcomes are fundamentally unpredictable, skeptics ask how *CAS* can guide policy choice rather than merely rationalize policy failure after the fact.

5.3 Normative and Democratic Accountability Concerns

A particularly important critique concerns the normative implications of *CAS* for democracy and accountability. *CAS-informed* governance often emphasizes decentralization, networks, self-organization, and experimentation (Dunlop et al., 2020). While these features enhance adaptability, they also complicate traditional democratic accountability mechanisms. In networked and adaptive systems, authority is dispersed rather than hierarchical; responsibility is shared rather than clearly assigned; and decisions emerge through interaction rather than formal mandates

This diffusion of authority can weaken transparency, blur lines of responsibility, and reduce citizens' ability to hold decision-makers accountable. Critics warn that *CAS* may unintentionally legitimize technocracy, managerial discretion, or informal governance arrangements that operate beyond democratic oversight (Rhodes, 1997).

There is also concern that self-organization and adaptation may reinforce existing power asymmetries. Actors with greater resources, expertise, or network centrality may disproportionately shape emergent outcomes, marginalizing weaker voices.

5.4 Implementation Barriers in Public Sector Contexts

Even when *CAS* principles are theoretically accepted, implementing them in public administration practice faces significant institutional and political barriers. Public sector organizations operate under legal constraints, budget cycles, audit regimes, and political scrutiny that often discourage experimentation and adaptation. Common implementation challenges are as follows:

- ***Risk aversion*:** Fear of failure, blame, and media scrutiny discourages experimentation.
- ***Rigid legal frameworks*:** Laws and regulations prioritize uniformity and compliance over flexibility.
- ***Performance management systems*:** Quantitative targets and indicators favor short-term outputs over long-term learning.
- ***Political time horizons*:** Electoral cycles incentivize visible results rather than adaptive capacity-building.
- ***Professional norms*:** Administrative cultures may resist decentralization and ambiguity.

As a result, *CAS-inspired* reforms may be rhetorically endorsed but practically neutralized by existing institutional logic.

5.5 Risk of Fragmentation and Inequality

Decentralization, diversity, and self-organization—hallmarks of *CAS*—can also generate fragmentation and uneven outcomes. When local units adapt independently, service quality, policy implementation, and citizen experiences may vary significantly across regions or social groups. Critics argue that CAS-informed governance may inadvertently exacerbate inequality if adaptive capacity is unevenly distributed. Wealthier jurisdictions, stronger organizations, or more connected networks may adapt successfully, while disadvantaged areas fall further behind (Rhodes, 1997; Osborne, 2010). Fragmentation also poses coordination challenges in policy areas requiring national coherence, such as public health standards, fiscal policy, or environmental regulation.

5.6 Methodological Challenges

Studying *CAS* in public administration presents methodological difficulties. Traditional quantitative methods often struggle to capture nonlinearity, feedback loops, and emergent dynamics. At the same time, qualitative approaches may lack generalizability. Operationalizing *CAS* concepts such as emergence or adaptation can be analytically demanding, and causal inference becomes more complex in systems characterized by mutual interaction and co-evolution.

6. Directions for Future Research

While *Complex Adaptive Systems (CAS) theory* has significantly enriched the conceptual understanding of public administration, it also opens a wide and still underexplored research frontier. Much of the existing literature remains theoretical or illustrative, with limited systematic empirical testing, methodological integration, and normative interrogation. Future research must therefore move beyond conceptual endorsement toward deeper empirical, methodological, and critical engagement with complexity-informed governance.

While leadership is frequently invoked in *CAS-oriented* governance, it remains under-theorized and under-measured. Future research should systematically examine what forms of leadership are effective in complex adaptive public systems and how such capacities can be developed.

A critical gap in existing *CAS-informed* public administration research concerns issues of power, inequality, and social equity. Complexity frameworks often emphasize emergence and self-organization without sufficiently interrogating whose interests shape emergent outcomes.

Future research must explicitly integrate *CAS* with critical perspectives by asking: how do power asymmetries influence adaptation and self-organization in governance systems? do complex systems reproduce or mitigate structural inequalities? how can equity and inclusion be deliberately embedded into adaptive governance designs? and what mechanisms ensure marginalized voices are not excluded from emergent decision processes? Bridging *CAS* with theories of social justice, representative bureaucracy, feminist institutionalism, and critical governance will strengthen the normative legitimacy of complexity-informed public administration.

CAS theory offers particular value for understanding long-term, systemic challenges such as climate change, public health preparedness, infrastructure resilience, and demographic transitions. These issues unfold over extended time horizons, involve multiple interacting systems, and resist linear

solutions (Holling, 1973; Duit et al., 2010; Ostrom, 2010).

Future research should examine: how public administration systems build and sustain resilience over time; the trade-offs between efficiency and redundancy in complex systems; institutional learning across crisis cycles; adaptive governance strategies for slow-moving but high-impact risks; and cross-scale interactions between local, national, and global governance systems.

7. Conclusion

This paper has advanced the argument that public administration is best understood not as a linear, hierarchical, and mechanistic enterprise, but as a *Complex Adaptive System (CAS)* operating within environments marked by uncertainty, interdependence, and rapid change. Contemporary governance challenges—ranging from climate change and pandemics to digital disruption, geopolitical instability, and social inequality—exceed the explanatory and operational capacities of traditional administrative models (Ostrom, 2010; Pollitt & Bouckaert, 2017). By integrating insights from complexity science, organizational theory, policy studies, and governance research, this article has demonstrated that a *CAS* perspective provides a more realistic and analytically robust framework for understanding how public administration actually functions.

Reframing public administration as a *CAS* challenges long-standing assumptions about control, predictability, and rational design. Administrative organizations, policymaking processes, and governance networks do not behave as stable machines governed by clear chains of command. Instead, they evolve through nonlinear interactions among diverse actors who adapt their behavior in response to feedback, constraints, and shifting environments. Outcomes emerge from practice rather than design, and stability is often provisional rather than permanent. Recognizing these dynamics does not imply governance failure; rather, it reveals the adaptive capacities through which public systems survive, learn, and transform (Hood, 1991, Torfing, 2019).

CAS theory illuminates core features of modern public administration that existing paradigms only partially capture. Administrative behavior is shaped by bounded rationality, discretion, informal norms, and institutional learning. Policymaking unfolds as an adaptive process characterized by feedback, path dependence, and episodic change. Governance increasingly occurs through networks and collaborative arrangements that distribute authority and responsibility across sectors and levels of government. Public sector innovation emerges from experimentation and learning rather than from centralized planning. Together, these dynamics underscore the inadequacy of purely hierarchical or market-based models and highlight the value of complexity-informed governance.

At the level of practice, the *CAS* perspective carries significant implications. It calls for adaptive leadership oriented toward sensemaking, facilitation, and system stewardship rather than command and control. It encourages institutional designs that balance stability with flexibility, decentralization with coordination, and experimentation with accountability. It foregrounds learning and feedback as central mechanisms of effective governance and reframes failure as a source of knowledge rather than solely a sign of incompetence. In crisis contexts, *CAS* highlights the importance of resilience, diversity, redundancy, and network activation over rigid contingency planning (Duit et al., 2010).

At the same time, this article has acknowledged that *CAS* is not a panacea. The application of complexity theory to public administration raises legitimate concerns regarding conceptual clarity, predictive capacity, democratic accountability, implementation feasibility, and equity. Complexity-informed governance can obscure responsibility, legitimize informal power, or exacerbate inequality if applied uncritically. These critiques underscore the need for disciplined theory use, methodological rigor, and explicit normative grounding. *CAS* must therefore be understood as a reflective framework rather than a prescriptive blueprint—one that complements, rather than replaces, established public administration theories and democratic institutions (Bovens, 2007; Dubnick & Frederickson, 2011).

Ultimately, embracing public administration as a complex adaptive system requires a shift in governance philosophy. It entails moving from prediction to preparedness, from optimization to adaptability, and from control to cultivation. This shift does not weaken the role of the state or undermine democratic accountability. Rather, it strengthens the capacity of public institutions to govern effectively in conditions where uncertainty is unavoidable and change is constant.

By aligning public administration theory and practice with the realities of complexity, *CAS* contributes to a more resilient, learning-oriented, and responsive public sector—one better equipped to create public value and sustain democratic governance in an increasingly complex world.

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TECHNICAL SCIENCES

OVERVIEW OF INFORMATION SYSTEMS TECHNOLOGIES IN TRANSPORTATION: METHODS, EXPERIMENTAL VAIDATION AND CRITICAL CHALLENGES OF INTELLIGENT TRANSPORTATION SYSTEMS

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Abstract

The Information systems (IS) acts as a key catalyst for the transformation of the traditional transportation industry into integrated cyber-physical systems (Intelligent Transportation Systems, ITS). This review systematically organizes the fundamental methodologies underlying this transformation, including sensory data collection, Vehicle-to-Everything (V2X) communication infrastructure, and advanced analytics based on Machine Learning and Digital Twins. Empirical validation demonstrates significant operational efficiency: pilot projects show a reduction in urban traffic delays by through adaptive control and fuel savings of up to in truck platoons.[1] Despite proven benefits, widespread adoption is constrained by critical unresolved issues, particularly the urgent need to develop attack-resistant V2X protocols and to standardize mechanisms for ensuring interoperability and data privacy.

Keywords: Information systems of Vehicle (ISoV), Intelligent Transportation Systems (ITS), V2X, Predictive Analytics, Digital Twins, Cybersecurity.

Introduction: Context and Systematization

Relevance and Transition to Cyber-Physical Transportation Systems

The concept of the IS involves the network integration of physical objects equipped with embedded sensors, actuators, and software for data exchange over the Internet. In the field of transportation, the Information systems, often called the Information systems of Vehicles (ISoV), is driving a fundamental revolution, transforming static infrastructure and vehicles (V) into dynamic, "smart" systems. This transformation marks a paradigm shift: moving from reactive traffic management and equipment maintenance to a predictive and adaptive mode, which substantially increases the safety, efficiency, and sustainability of the transportation network [1].

The Architectural Role of IS in the Transportation Ecosystem (ISoV)

IS in transportation represents a complex network architecture that connects vehicles, equipment, infrastructure, and objects via embedded sensors, communication devices, and software. This integration allows for the collection, analysis, and transmission of petabytes of data in real-time. Key application areas where this convergence is critical include urban traffic flow management and the creation of "Smart" Cities (through adaptive traffic lights and infrastructure monitoring), optimization of fleet management and logistics (through telematics and cargo monitoring), and ensuring technical maintenance and safety, which is the foundation for the development of autonomous driving (ADAS/AV).

Review Structure and Contribution

The goal of this review study is to systematize the key technological methods used for IS implementation in ITS, present detailed quantitative data confirming their effectiveness, and conduct a critical analysis of open challenges. The following sections detail the sensing and communication layers, describe analytical methods (ML, Digital Twins), provide results of empirical validation in key sectors (ITS, logistics, railway), and discuss pressing challenges in cybersecurity and standardization.

Technological Foundations and Implementation Methods

Sensing Layer and Telematic Data Collection

The foundation of any IS-based ITS is laid at the data collection level, which is provided by a combination of specialized sensory modules. GPS modules and accelerometers are used for monitoring location and speed. For autonomous and semi-autonomous driving, more complex, high-precision sensors are required, such as LiDAR, radars, and cameras, which collect data about the environment and objects (fig.1).

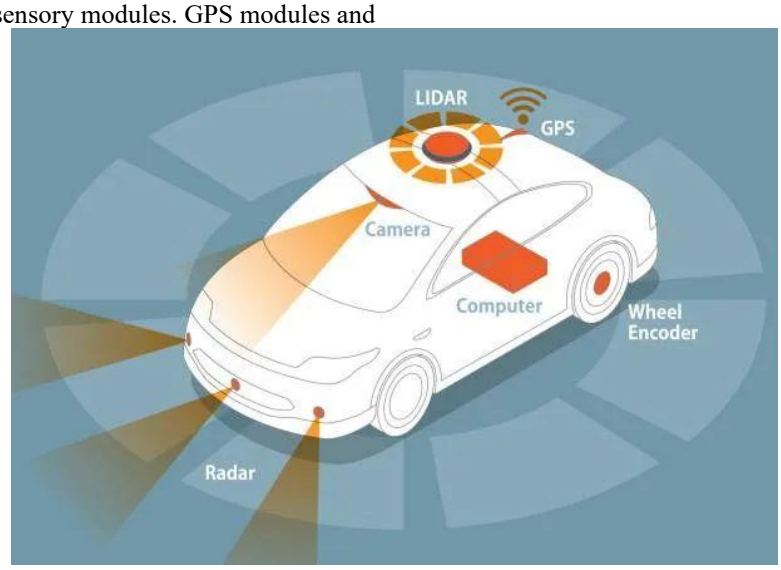

Fig.1. Sensors for autonomous and semi-autonomous driving

A critical method for predictive maintenance is the integration of IS devices with onboard diagnostic systems (OBD-II). This integration allows for collecting detailed data on the technical condition of the vehicle itself, including engine operation, component wear, and other operational parameters. This data, obtained via OBD-II, is the basis for transitioning from scheduled maintenance to "on-demand" repair, significantly reducing accident rates and operational costs.

Communication Infrastructure (V2X)

Data transmission in ITS relies on ultra-low latency communication standards, such as 5G/4G (LTE), NB-IS, and LoRaWAN. The central element of the communication strategy is V2X (Vehicle-to-Everything), which ensures interaction between various entities in the transportation ecosystem: V2V (Vehicle-to-Vehicle), V2I (Vehicle-to-Infrastructure), and V2P (Vehicle-to-Pedestrian) [2].

V2X communication is essential for road safety applications, traffic management, and coordination of autonomous vehicles [3]. It should be noted that the efficiency of all adaptive and autonomous IS applications, such as dynamic traffic light control or platooning, directly depends on the reliability and minimal latency of the V2X channel. Any increase in delay or failure at this level can negate the calculated benefits, such as the reduction of congestion by , and moreover, create a direct safety threat. Thus, ensuring ultra-reliable, low-latency communication is not just a technical requirement, but a critical factor for realizing all the promised benefits of intelligent systems [4].

Analytical Layer: Big Data, Machine Learning, and Predictive Modeling

The massive volumes of data generated by thousands of connected devices (Big Data) require specialized technologies for storage, processing, and analysis. At this level, predictive analytics, based on Machine Learning (ML) methods, plays a key role.

ML algorithms are used to solve a multitude of tasks: from forecasting vehicle component failures to dynamically calculating the most efficient routes based on current traffic and weather data. Journals such as "APL Machine Learning" regularly publish research dedicated to the application of these approaches in physical sciences and ITS, emphasizing their role in creating more sophisticated control algorithms [5].

Virtualization and Forecasting: Digital Twins

The concept of Digital Twins (DT) involves creating an accurate virtual copy of a physical object or an entire transport infrastructure. These twins are used for simulation, remote monitoring, and prognostic analysis in a controlled environment (fig.2).

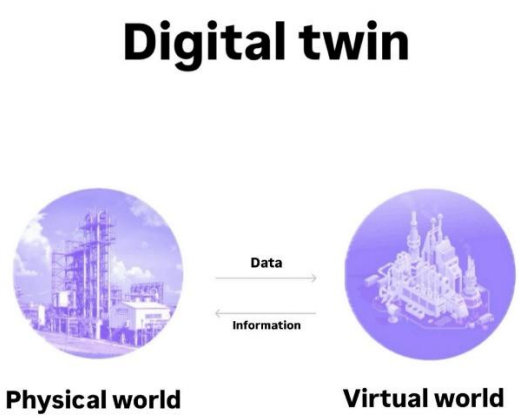

Fig.2. The concept of Digital Twins

The application of DT allows for substantial optimization of transport industry management. Specifically, DTs can be used both at the stage of designing transport infrastructure and during its operation for diagnostics and forecasting. This approach allows for shifting resource-intensive empirical testing to a virtual environment, leading to significant savings of physical, financial, and material resources [6]. Data continuously flowing from IS sensors is used to calibrate the Digital Twin, and the results of modeling in the DT, in turn, optimize real-world decisions, thereby completing the cycle of intelligent management.

Table 1:

Summary Table of Technological Methods for IS Implementation in ITS

Functional Category	Key Technologies	Key Role in ITS
Data Collection (Sensing)	GPS, LiDAR/Radar, Accelerometers, OBD-II	Monitoring vehicle and environment status, foundation for ADAS/AV
Communication (V2X)	V2V, V2I, V2P, 5G/LTE, LoRaWAN	Ultra-reliable and low-latency communication for coordination
Analysis and Forecasting	Big Data, Machine Learning, Predictive Analytics	Traffic forecasting, route optimization, early fault detection
Modeling	Digital Twins	Virtual testing, remote diagnostics, and management

Review of Experimental Applications and Empirical Validation

Intelligent Urban Traffic Management (ITS)

The implementation of adaptive traffic lights, equipped with IS sensors, allows for dynamically adjusting signal timing based on the analysis of current traffic flow. This method is directly opposite to traditional fixed systems and has proven highly effective.

Results from pilot projects in urban ITS demonstrate a reduction in congestion and overall movement delay ranging from to due to adaptive control. Further development includes the use of advanced algorithms such as Deep Reinforcement Learning (DRL). Simulation results show that hybrid DRL-GA systems can not only improve traffic flow (reducing delay by) but also achieve a reduction in energy consumption by . Thus, empirical data confirms that IS solutions in ITS successfully serve a dual purpose: increasing operational efficiency and achieving environmental sustainability goals, which is a critically important justification for investment in the concept of "smart" and "green" cities [7].

Predictive Maintenance of Vehicles and Infrastructure

Predictive Maintenance (PdM) uses sensor data on vehicle and infrastructure operation to forecast potential failures, allowing for a transition from costly scheduled maintenance to repair based on actual need.

In rail transport, this method involves installing IS sensors on key locomotive nodes (engines, wheels). Analysis has shown that such a system can reduce sudden in-transit malfunctions by and increase the intervals between scheduled repairs. Studies applying Machine Learning algorithms to railway signal status data confirm the high prognostic value of this approach: the algorithm was able to successfully predict of signal failures a month before they actually occurred. The success of such systems directly depends on the integration of heterogeneous data sources. For example, studies have shown that not only technical telemetry but also exter-

nal factors, such as extreme weather conditions (especially high temperature), have significant predictive value for assessing future equipment failures [8].

Smart Logistics: Monitoring the "Cold Chain"

The logistics of perishable or condition-sensitive goods (pharmaceuticals, food) requires strict adherence to temperature and humidity regimes, known as the "cold chain."

The method involves using multiple wireless IS sensors inside containers for continuous monitoring of transport conditions. Experimental projects have shown that these systems provide automatic alerts about storage condition violations, which is critical for enhancing cargo preservation. These systems, often complemented by online decision-support, can significantly reduce transportation losses. However, implementation faces challenges related to the physical environment: difficulties with powering autonomous IS devices in mobile conditions and unreliable data transmission in remote areas with poor network coverage can jeopardize the reliability of the monitoring system [9-11] (fig.3).

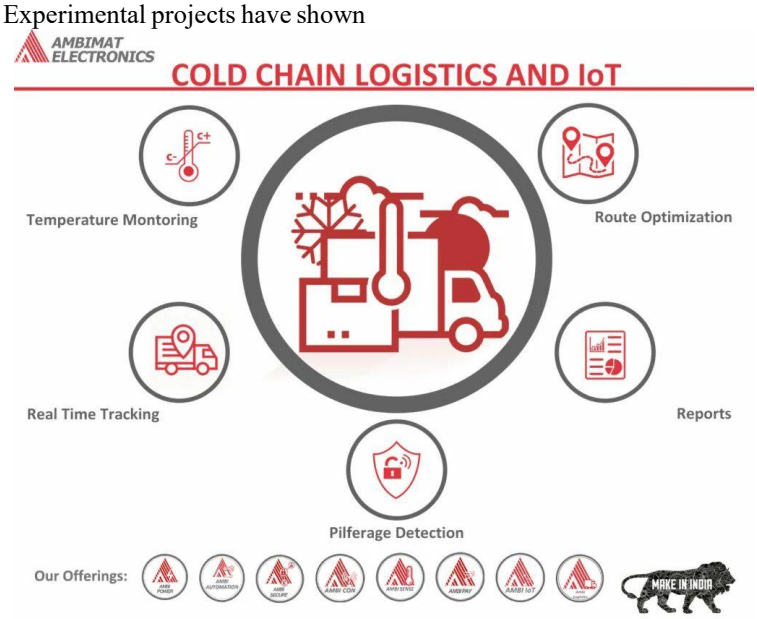

Fig.3. Utilization cold chain logistics and IS

Autonomous Systems: Truck Platooning

Truck platooning is the automated movement of several trucks at a minimal distance from each other, coordinated using V2V communication.

The main goal of platooning is to reduce aerodynamic drag, which leads to significant fuel savings. Experimental data confirm that, depending on the distance and size of the platoon, the reduction in the drag coefficient can reach. Based on this aerodynamic gain, fuel savings of up to are achieved for the following trucks. It should be noted that the economic efficiency of platooning directly depends on the V2V system's ability to safely maintain a minimum distance (e.g., 1–4 m) between vehicles. Thus, the maximum aerodynamic gain is entirely predicated on ensuring ultra-reliable, safe, and low-latency V2X communication, especially in scenarios requiring synchronized emergency braking.

Table 2:

Comparative Analysis of Experimental Applications and Results

Application	Key IS Method	Key Measured Outcome	Quantitative Performance Indicators
Urban ITS	Adaptive traffic lights (Sensing + ML/DRL)	Reduction in traffic delays and energy consumption	Congestion reduction: Energy consumption reduction:
Truck Platooning	V2V communication and automation	Fuel savings due to aerodynamics	Up to fuel savings; reduction in drag coefficient
Predictive Maintenance	Sensing + Predictive analytics (ML)	Reduction in sudden malfunctions, failure forecasting	reduction in sudden malfunctions; of failures predicted in advance
"Cold Chain"	Wireless temperature IS sensors	Increased preservation of critical cargo	Automatic alert upon condition violation

Critical Challenges, Open Questions, and Research Perspectives

The widespread and safe deployment of IS in the transportation sector faces a number of systemic challenges requiring immediate attention from the academic community and regulators.

Cybersecurity of V2X Communication Protocols

The most acute challenge is the cybersecurity of connected transportation systems. Security threats associated with hacking V2X communication can have catastrophic consequences for road safety, as hackers can manipulate messages about location, speed, or collision warnings [12].

Research in V2X security focuses on analyzing protocols such as Dedicated Short-Range Communications (DSRC) and Cellular V2X (C-V2X), and their mechanisms for authentication, encryption, and certificate management. Standard protocols based on Message Authentication Code (MAC) and Elliptic Curve Digital Signature Algorithm (ECDSA) are applied to ensure the integrity and authenticity of transmitted data [13].

However, there is a fundamental trade-off between the need for absolute security (encryption and authentication) and the requirement for minimal latency, which is critical for road safety applications. The implementation of complex cryptographic security measures inevitably increases communication overhead, which can potentially violate the strict time limits required for V2X applications. Thus, future research must be directed towards finding the optimal balance between cryptographic strength and data processing speed. Furthermore, over-specialization of V2X security limits broad collaboration with the general cybersecurity community. Simplification and increased transparency of V2X protocols are necessary conditions for developing more robust countermeasures and increasing public trust in autonomous and connected systems.

Privacy and Ethical Issues

The collection of enormous volumes of real-time vehicle movement data raises serious questions about the privacy of personal information. Analytical systems can not only track routes but also form detailed profiles of driver behavior. This urgently requires the development of robust standards for data aggregation and anonymization that must maintain high analytical value for traffic optimization while excluding the possibility of ultimate user de-anonymization.

Interoperability and Standardization

The existing transport infrastructure often consists of fragmented, proprietary systems, which creates significant obstacles to integration. To implement a fully scalable and efficient ITS, seamless interaction between different vehicle manufacturers, infrastructure components, and cloud services must be ensured. The issue of interoperability requires global standardization of data formats and Application Programming Interfaces (APIs), which remains one of the key organizational and technical challenges.

Conclusion

Information systems technologies are the key driving force transforming transportation, offering measurable improvements in efficiency and safety. The success of ISoV depends on the synergy between an advanced sensing layer (LiDAR, OBD-II), ultra-reliable V2X communication protocols, and cutting-edge analytics based on Machine Learning and the Digital Twins concept. Empirical validation confirms the ability of these systems to reduce delays by in urban settings and achieve up to fuel savings in logistics, as well as enhance infrastructure reliability through predictive maintenance.

The primary tasks for further research are focused on critical risks: the development of lightweight but cryptographically robust V2X protocols to resolve the dichotomy between security and low latency, and the development of standardized methodologies to ensure interoperability and privacy protection in a heterogeneous network infrastructure. Addressing these challenges will allow for the definitive realization of the potential of integrated, safe, and sustainable transportation systems of the future.

Authors' Declaration

The authors declare no conflict of interests regarding the publication of this article

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DYNAMIC ANALYSIS OF HYGROTHERMAL REGIME OF MASSIVE ADAPTED UNDERGROUD REINFORCED CONCRETE STRUCTURES

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ДИНАМІЧНИЙ АНАЛІЗ ГІГРОТЕРМІЧНОГО РЕЖИМУ МАСИВНИХ АДАПТОВАНИХ ПІДЗЕМНИХ ЗАЛІЗОБЕТОННИХ СПОРУД

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Abstract

The article presents a quantitative analysis of the hygrothermal regime of an adapted underground civil defense building, which is increasingly characterized by long-term occupancy by a significant number of people. Such buildings are characterized by significant thermal and moisture inertia due to massive reinforced concrete enclosing structures in contact with the ground. This ensures high stability of the internal temperature, but at the same time creates a risk of condensation on cold surfaces in the summer, when ventilation air with high humidity enters the building. The behavior of the structures during typical summer "hot" and winter "cold" periods was analyzed. The results of observations for the summer period demonstrate that the temperature of the inner wall surface remains stably below the dew point of the air in the building during operating hours, resulting in a significant accumulation of condensate. The relative humidity on the wall surface exceeds 80% for long periods, which creates a high risk of microbiological corrosion (mold) according to ASHRAE 160 criteria. The study confirms the hypothesis that the direct application of modern ventilation standards, especially uncontrolled ventilation, without taking into account the unique thermophysical properties of massive underground structures is unacceptable. Based on the analysis of various engineering strategies (ventilation, dehumidification, insulation), it is concluded that the integration of air dehumidification systems is the most effective method of controlling humidity and preventing structural degradation.

Анотація

У статті представлено кількісний аналіз гігротермічного режиму адаптованого підземного приміщення цивільного захисту, що все більше характеризується довготривалим перебуванням значної кількості осіб. Такі споруди характеризуються значною тепловою та вологісною інерцією завдяки масивним залізобетонним огороджувальним конструкціям, що контактують із ґрунтом. Це забезпечує високу стабільність внутрішньої температури, але водночас створює ризик утворення конденсату на холодних поверхнях у літній період, коли вентиляційне повітря з високою вологістю потрапляє всередину. Було проаналізовано поведінку конструкцій протягом характерних літнього "спекотного" та зимового "холодного" періодів. Результати спостережень для літнього періоду демонструють, що температура внутрішньої поверхні стіни стабільно залишається нижчою за точку роси повітря в приміщенні протягом годин експлуатації, що призводить до значного накопичення конденсату. Відносна вологість на поверхні стін перевищує 80% протягом тривалих періодів, що створює високий ризик розвитку мікробіологічної корозії (плісняви) згідно з критеріями ASHRAE 160. Дослідження підтверджує гіпотезу про те, що пряме застосування сучасних норм вентиляції, особливо неконтрольованого провітрювання, без урахування унікальних теплофізичних властивостей масивних підземних споруд є неприпустимим. На основі аналізу різних інженерних стратегій (вентиляція, осушення, утеплення) зроблено висновок, що інтеграція систем осушення повітря є найбільш ефективним методом контролю вологості та запобігання деградації конструкцій.

Keywords: thermal inertia, moisture inertia, underground structures, condensation, dew point, duilding physics.

Ключові слова: теплова інерція, вологісна інерція, підземні споруди, конденсація, точка роси, будівельна фізика.

1. Вступ

Тенденція до адаптації існуючих підземних споруд цивільного захисту для громадського використання, наприклад, як музеї, галереї, навчальні простори чи паркінги, набуває все більшої актуальності. Однак таке перепрофілювання створює значні інженерні виклики, оскільки вихідні проєктні рішення цих об'єктів кардинально відрізняються від вимог до сучасних громадських будівель. Ключовою особливістю таких споруд є їхня масивна огороджувальна конструкція, зазвичай із залізобетону, що знаходиться в прямому контакті з ґрунтом. Це надає їм величезну теплову інерцію — здатність накопичувати та повільно віддавати тепло, що забезпечує виняткову стабільність внутрішньої температури протягом року [1].

Проблема виникає внаслідок конфлікту між цією фізичною властивістю та сучасними вимогами до якості повітря в приміщеннях. Для забезпечення комфорту та здоров'я відвідувачів такі простори обладнуються системами вентиляції, розрахованими згідно з чинними нормативами, такими як ДБН В.2.5-67:2013 [2] або ASHRAE 62.1 [3]. У літній період ці системи подають у приміщення тепле та вологе зовнішнє повітря. У той час як повітря всередині швидко нагрівається від людей та освітлення, масивні стіни, температура яких близька до середньорічної температури ґрунту, залишаються холодними. Це створює ідеальні умови для утворення конденсату на внутрішніх поверхнях.

Наслідки цього явища є руйнівними як для будівлі, так і для її вмісту та відвідувачів. Для обладнання та меблів надлишкова вологість призводить до незворотних пошкоджень: органічні матеріали (папір, дерево, тканина) деформуються та гниють, металеві предмети інтенсивно кородують, а на поверхнях розвивається пліснява, що руйнує фарби та структуру об'єктів. Для тривалого перебування людей сира атмосфера сприяє розмноженню патогенних мікроорганізмів, спори яких можуть викликати алергії та астму, а також знижує концентрацію та працездатність.

Пряме застосування сучасних норм вентиляції, розроблених для типових надземних будівель з низькою тепловою інерцією, без комплексного аналізу фізики огороджувальних конструкцій, призводить до збою системи. Вентиляція, призначена для покращення здоров'я, ненавмисно створює умови, що загрожують як здоров'ю людей (пліснява), так і збереженню самої будівлі.

2. Мета та задачі дослідження

Основна мета цього дослідження — кількісно оцінити гігротермічний режим адаптованого університетського бомбосховища, зосереджуючись на ризику літньої конденсації.

Центральна гіпотеза полягає в тому, що висока теплова інерція масивних бетонних огороджувальних конструкцій за типових літніх кліматичних умов та стандартних норм вентиляції призведе до того, що температура внутрішньої поверхні стін буде систематично опускатися нижче точки роси внутрішнього повітря, спричиняючи конденсацію.

Додаткові цілі включають оцінку поведінки конструкції в зимовий період для визначення її потенціалу до висихання та аналіз різних інженерних стратегій (вентиляція, осушення, утеплення) для запобігання таким ризикам.

3. Об'єкті предмет дослідження

Адаптація існуючих підземних споруд цивільного захисту (бомбосховищ) під довготривале громадське використання (музеї, аудиторії) є актуальною інженерною проблемою. Об'єкт дослідження — підземне приміщення університету загальною площею 2000 м^2 та об'ємом ≈ 5400 м^3. Огороджувальні конструкції представлені масивним залізобетоном товщиною 0.60 м.

Ключовий виклик пов'язаний із тепловою інерцією цих конструкцій. Внаслідок контакту із ґрунтом температура стін (T_{surf}) утримується на низькому рівні (стабільно $\sim 16 - 17$ °C), що повільно реагує на зовнішні коливання. У літній період, коли подається тепле та вологе зовнішнє повітря, його температура точки роси (T_{dp}) може перевищувати T_{surf}, спричиняючи поверхневу конденсацію.

Наслідки неконтрольованої вогкості (вологість понад ~ 70 RH) є неприйнятними: ризик розвитку плісняви, пошкодження музейних експонатів (корозія, деформація органічних матеріалів), та негативний вплив на здоров'я (алергії, астма). Для збереження цінностей потрібен оптимальний мікроклімат: $40 - 60$ RH при $18 - 22$ °C.

4. Методи досліджень

Для адекватної оцінки вологого режиму масивних конструкцій потрібні методи нестаціонарного (динамічного) гігротермічного аналізу (HAM-аналіз).

Таблиця 1.

Порівняльна характеристика стандартів та методів аналізу

Критерій	ДСТУ EN ISO 13788 [4] (стаціонарний)	ДСТУ EN 15026 [5] (динамічний)	ДБН В.2.6-31 [2] (нормативний)	ASHRAE 160 [3] (критеріальний)
Принцип	Усереднені дані, стаціонарний потік	Погодинні дані, нестаціонарний аналіз	Мінімальні вимоги до R, спрощений аналіз	Критерії до результату (performance-based)
Врахування теплової інерції	Ні	Так (ключова перевага)	Ні	Вимагає методів, що її враховують
Прогноз літньої конденсації	Хибно-негативний	Точний та кількісний	Хибно-негативний	Надає критерії для оцінки ризику
Складність та вимоги	Низька	Висока (погодинні дані, ПЗ)	Низька	Висока (вимагає результатів моделювання)
Придатність для об'єкта	Непридатний	Єдиний придатний метод розрахунку	Непридатний для аналізу вологості	Для постановки цілей та оцінки

Таким чином, таблиця чітко ілюструє, що лише комплексний підхід, який поєднує динамічне моделювання та критеріальну оцінку, є адекватним для вирішення поставленої інженерної задачі.

Важливим стандартом для оцінки ризиків вологості є ASHRAE Standard 160 "Критерії для проєктного аналізу контролю вологості в будівлях". Це не метод розрахунку, а стандарт, що встановлює критерії оцінки результатів, отриманих за допомогою динамічного моделювання (як у ДСТУ EN 15026). Прямого аналога в Україні немає, але він використовується як еталон передової інженерної практики. Стандарт вимагає уникнення тривалого підтримання відносної вологості на поверхні (RH_{surf}) вище 80 (при температурі 5 ... 40 °C), що є критичним порогом для росту плісняви.

Об'єкт дослідження: 500 м² музейної зони у підвалі університету. Огороджувальні конструкції, монолітний залізобетон 0.60 м товщини протяжністю 46м.

Таблиця 2.

Теплофізичні властивості будівельних та ґрунтових матеріалів

Матеріал	Щільність (ρ) [кг/м³]	Теплопровідність (λ) [Вт/(м·К)]	Питома теплоємність (c) [Дж/(кг·К)]	Опір дифузії пари (μ)
Залізобетон	2400	1,7	840	100
Ґрунт (суглинок)	1600 (у тілі)	1,2	900	30

В рамках дослідження проведено безперервне погодинне фіксування із точністю ±0.6°C для температури і ±5% RH для вологості таких параметрів [6]:

- Зовнішні параметри ($T_{\text{out}}, RH_{\text{out}}$).
- Внутрішні параметри ($T_{\text{in}}, RH_{\text{in}}$).
- Поверхневі параметри ($T_{\text{surf}}, RH_{\text{surf}}$): Вимірювання у найхолодніших зонах (нижня частина стіни) для контролю конденсації.

Моніторинг охоплював два критичні періоди:

- Літній період (9 діб): "спекотний", T_{out} коливалася від $+18 \ldots +20$ °C вночі до $+28 \ldots +33$ °C вдень. При цьому відносна вологість зовнішнього повітря (RH) була підвищеною, сягаючи ~70–80% в нічний час.
- Зимовий період (9 діб): Період "сталої холодної погоди" з T_{out} у діапазоні $-8 \ldots 0$ °C.

Таблиця 3.

Сценарії дослідження впливу на тепловологісний режим приміщення.

Сценарій	Сезон	Опис та ключові умови	Вплив на $T_{dp,\,in}$
A (Базовий)	Літо/Зима	Мінімальна інфільтрація (~0.1 год−1), вентиляція лише для CO2 контролю (09:00–18:00).	$T_{dp,\,in}$ зростає відповідно до зовнішньої вологості та внутрішніх надходжень.
B (Нічна Вентиляція)	Літо	Інтенсивна примусова вентиляція (~2.0 год−1) вночі (22:00–06:00).	Підвищує $T_{dp,\,in}$ та RH уночі, оскільки затягує прохолодне, але вологе повітря.
C (Осушення Повітря)	Літо/Зима	Активне осушення (ціль RH≈55%). Обмежує $T_{dp,\,in}$ до безпечного рівня (~13−14 °C влітку).	Різке зниження $T_{dp,\,in}$ та усунення ризику конденсації.
D (Вентиляція з Підігрівом)	Зима	Подача підігрітого свіжого повітря, яке взимку є абсолютно сухим. Влітку не застосовується.	Взимку підтримує $T_{dp,\,in}$ на низькому, стабільному рівні, забезпечуючи висихання конструкцій.

Аналіз даних включав:

- Критерії конденсації: Порівняння T_{surf} з температурою точки роси повітря у приміщенні ($T_{dp,\,in}$).
- Ризик плісняви: Визначення кількості годин, коли $RH_{in} > 70$.
- Кількісна оцінка: Оцінка загального накопичення конденсату (130.2 г/м^2).
-

Таблиця 4.

Параметри та графіки внутрішніх навантажень для музейної зони

Параметр	Значення	Час
Кількість відвідувачів	50 осіб (будні), 100 осіб (вихідні)	Протягом 09:00–18:00
Вентиляція	1200 м³/год (приплив зовнішнього повітря)	5 год
Вологовиділення від людей	90 г/год на особу	до 2 год перебування
Тепловиділення від людей	75 Вт (явне), 60 Вт (приховане) на особу	до 2 год перебування
Тепловиділення від освітлення	10 Вт/м² (5000 Вт загалом)	8 год
Цільова температура повітря	+21 °C	Цілодобово

5. Результати досліджень

Протягом 9 діб літнього періоду послідовно випробувано три сценарії вентиляції/осушення (A, B, C), наведені в Таблиці 1. Усі вони мали однакові внутрішні тепловологісні навантаження, різнились лише стратегією повітрообміну в приміщенні [7]:

A (Базовий сценарій): мінімальна інфільтрація (~0,1 год⁻¹); примусова вентиляція включається лише вдень за потреби (еквівалентно ~0,8 год⁻¹ з 09:00 до 18:00). У цьому випадку надлишкова волога відвідувачів накопичується у повітрі, особливо в неробочі нічні години. Точка роси в залі ($T_{dp,in}$) поступово підвищується від ~10–12 °C (вранці) до ~17–18 °C наприкінці дня, наближаючись до холодної температури стін. Це означає, що вже у перші ж ночі $T_{dp,in}$ досягає T_{surf}, і на стінах починає випадати конденсат. Моделювання показує, що конденсація в сценарії A відбувалася майже щоночі; загальний накопичений конденсат за 9 діб оцінено ~130 г води на кожен м² холодної поверхні. Відносна вологість повітря RH_{in} у базовому режимі більшу частину часу перевищувала 70% (понад 80% часу), що вказує на високий ризик розвитку плісняви. Отже, базовий режим є неприйнятним: уже при короткочасному підвищенні вологості зовнішнього повітря поверхні систематично зволожуються конденсатом.

B (Нічна вентиляція): інтенсивна нічна подача зовнішнього повітря (~2,0 год⁻¹ з 22:00 до 06:00) на додачу до базової денній вентиляції. Мета – охолодити і провітрити залу вночі. Наслідком стає підвищення вологості: прохолодне нічне повітря при 70–80% RH_{out} містить багато вологи, яку вентиляція нагнітає всередину. Точка роси в приміщенні різко зростає до ~18 °C у нічні години, що призводить до конденсації на стінах щоночі (як і в сценарії A). Водночас посилений повітрообмін видаляє частину вологи, тому вдень RH_{in} дещо нижча, ніж у базовому випадку. Розрахунки показують, що за сценарієм B внутрішня вологість перебувала понад 70% приблизно 60% часу. Таким чином, нічна вентиляція лише частково зменшує середню вологість у залі, але не усуває конденсацію. Це узгоджується з відомим правилом: вентиляція є ефективною проти вологи тільки тоді, коли точка роси зовнішнього повітря нижча за внутрішню – інакше вологе повітря лише додає вологи всередині. В нашому випадку нічна $T_{dp,out}$ (~15–16 °C) була приблизно рівна або навіть вища за денну $T_{dp,in}$, тож нічна подача повітря погіршувала ситуацію. Звідси випливає, що нічне провітрювання підвалу вологим літнім повітрям недоцільне.

C (Осушення повітря): постійно працює електричний осушувач, який підтримує $RH_{in} \approx 55$. Вентиляція при цьому мінімізована (лише короткочасно в робочі години для комфорту). Цей сценарій повністю запобіг конденсації. Точка роси всередині стабільно трималася на рівні ~13 °C і ніколи не наближалася до 18 °C стін. Відносна вологість не перевищувала безпечних ~55%, тож години з $RH >$

70 взагалі відсутні. Осушення різко знижує $T_{dp,in}$ та усуває ризик конденсації навіть у пікові моменти надходження вологи. За розрахунками та спостереженнями, конденсату на стінах не утворюється, а поверхні поступово підсихають. Недоліком є витрати енергії на осушення, але цей режим гарантовано захищає експонати та конструкції.

Графічна інтерпретація (літо): на нижченаведеному графіку показано зміну температури точки роси повітря в залі ($T_{dp,in}$) за кожним сценарієм протягом 9 діб (кожен сценарій по 3 доби), у порівнянні з точкою роси зовнішнього повітря та температурою поверхні стін:

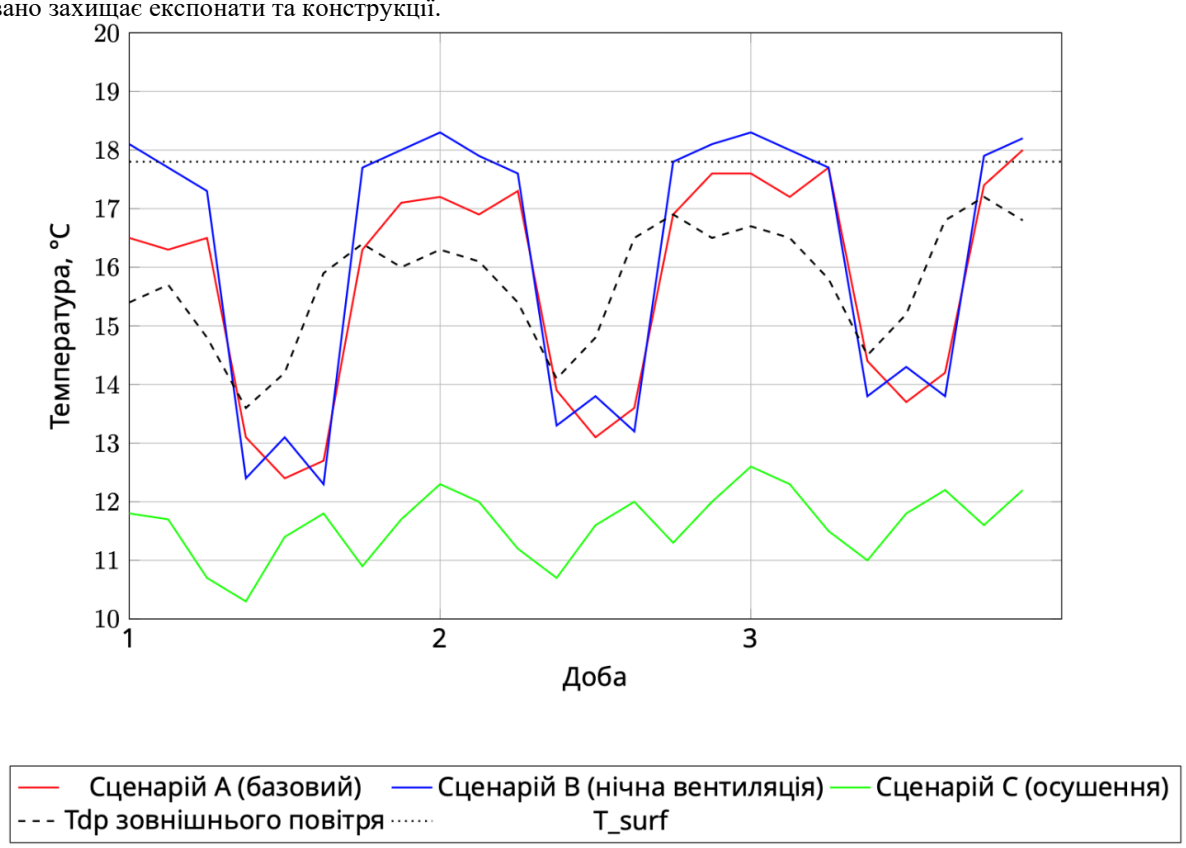

Рис. 1: Динаміка точки роси для трьох сценаріїв у літній період.

Літній період: добові коливання точки роси. Червона лінія – базовий сценарій А; синя – сценарій В з нічною вентиляцією; зелена – сценарій С з осушенням. Чорна штрихова лінія показує точку роси зовнішнього повітря, чорна пунктирна лінія – постійну температуру внутрішньої поверхні стіни. Видно, що в сценаріях А і В внутрішня точка роси регулярно досягає 18 °C (перетинає пунктир), тобто виникає конденсація. В сценарії С точка роси тримається безпечно низько, і конденсат не випадає.

Таблиця 1 узагальнює результати для літнього періоду. У базовому режимі А подача вологого повітря призводить до постійного зволоження стін; нічна вентиляція В не усуває цю проблему , хоча й дещо зменшує загальну вологість удень. Лише осушення С забезпечує умови без конденсації та плісняви. Загалом, для літнього періоду критично важливо обмежувати надходження вологи: рекомендовано сценарій С (активне осушення) як базовий засіб захисту адаптованих підземних приміщень влітку. Альтернативно, можна поєднувати помірну вентиляцію із кондиціонуванням чи осушенням, але не впускати неконтрольовано вологе повітря. Така альтернатива потребує автоматизації кліматичних систем.

Таблиця 5.

Порівняння сценаріїв контролю вологості (літній період, 9 діб).

Сценарій	Опис умов	Конденсація на стінах	Температура стін T_{surf}	Макс. точка роси $T_{dp,in}$ в приміщенні	Годин з $RH_{in} > 70\%$
A (базовий)	Мінімальна вентиляція (тільки вдень при потребі). Вологість накопичується.	Постійно щоночі, ~130 г/м² конденсату	≈18,0…18,6 °C	17-18	~85% часу (дуже високий ризик)
B (нічна вент.)	Інтенсивне провітрювання щоночі (2 год⁻¹). Зовн. повітря: прохолодне, але вологе. Вентиляція вдень при потребі.	Щоночі (точка роси ~18 °C), кількість близька до A	≈17,9…18,3 °C	18	~60% часу (все ще високий)
C (осушення)	Осушувач підтримує RH≈55%. Мінімальна вентиляція (тільки вдень при потребі).	Немає	≈18,3…18,6 °C	12-13	0% часу (норму дотримано)

Результати моніторингу для зимового періоду.

У холодний період були досліджені базовий режим A (мінімальна інфільтрація + денна вентиляція при потребі), режим C (осушення до 55% RH) та спеціальний сценарій D (постійна вентиляція з підігрівом повітря). Сценарій B у мороз не застосовувався. При такому ж внутрішньому тепловологісному навантаженні отримано настпні результати за сценаріями:

A (Мікроклімат без втручань): У базових умовах взимку підвал сам по собі залишався у безпечному стані. Мінімальна інфільтрація холодного повітря (0,1 год⁻¹) забезпечувала осушення: точка роси всередині трималася на рівні ~6–11 °C, що значно нижче температури стін ~15 °C. Конденсації не спостерігалося (бо Tsurf >> Tdp,in), навпаки – внутрішні поверхні поступово підсихали. Відносна вологість у приміщенні коливалася в межах ~45–60% (навіть у години масового відвідування не перевищувала ~60%), тобто RH_{in} жодного разу не перевищила 70%. Наш випадок – комфортніший, адже вентиляція мінімальна і RH_{in} залишається в здоровому діапазоні. Таким чином, у зимовий період навіть без спецзаходів ризик конденсації відсутній, а ризик плісняви мінімальний.

C (Активне осушення): У зимових умовах активний осушувач майже не має роботи, оскільки повітря і так достатньо сухе. Спостереження показують, що при ввімкненому осушувачі RH_{in} утримується ~45–50%. Точка роси залишається близькою, як у сценарії A (~5–9 °C). Конденсації немає. Тобто результати сценаріїв A та C взимку практично ідентичні. Осушення можна використовувати як додаткову гарантію, але природного осушувального ефекту холодного повітря достатньо, щоб утримувати підвал сухим.

D (Вентиляція з підігрівом): Цей режим забезпечується роботою приточно-витяжної системи, що цілодобово подає значний об'єм зовнішнього повітря, але підігріває його до +21 °C для комфорту. В таких умовах абсолютна вологість у приміщенні різко падає – зовнішнє морозне повітря, навіть якщо приходить насиченим (100% RH при –8…0 °C), після нагрівання стає сухим (RH порядку 40%). Сценарій D показує, що внутрішня точка роси опускається до ~–5…0 °C і практично дорівнює точці роси зовнішнього повітря. Це означає, що всі конструкції інтенсивно підсушуються: волога з матеріалів випаровується в сухе повітря і вилучається вентиляцією. Відносна вологість у залі вдень могла знижуватися менше 40%, надто сухе повітря може шкодити музейним предметам. Отже, режим D ефективно ліквідує будь-які сліди конденсації чи сирості, але потребує контролю рівня вологості, щоб не пересушити. На практиці варто застосовувати помірний підігрів/вентиляцію лише до досягнення безпечної вологості матеріалів, після чого підтримувати більш збалансований режим.

Графік для зимових сценаріїв: нижче наведено зміни точки роси повітря в підвалі за сценаріями A (мінімальна вентиляція), C (активне осушення) та D (інтенсивна вентиляція) протягом 9 зимових діб (кожен сценарій по 3 доби), у порівнянні з точкою роси зовні та температурою стін:

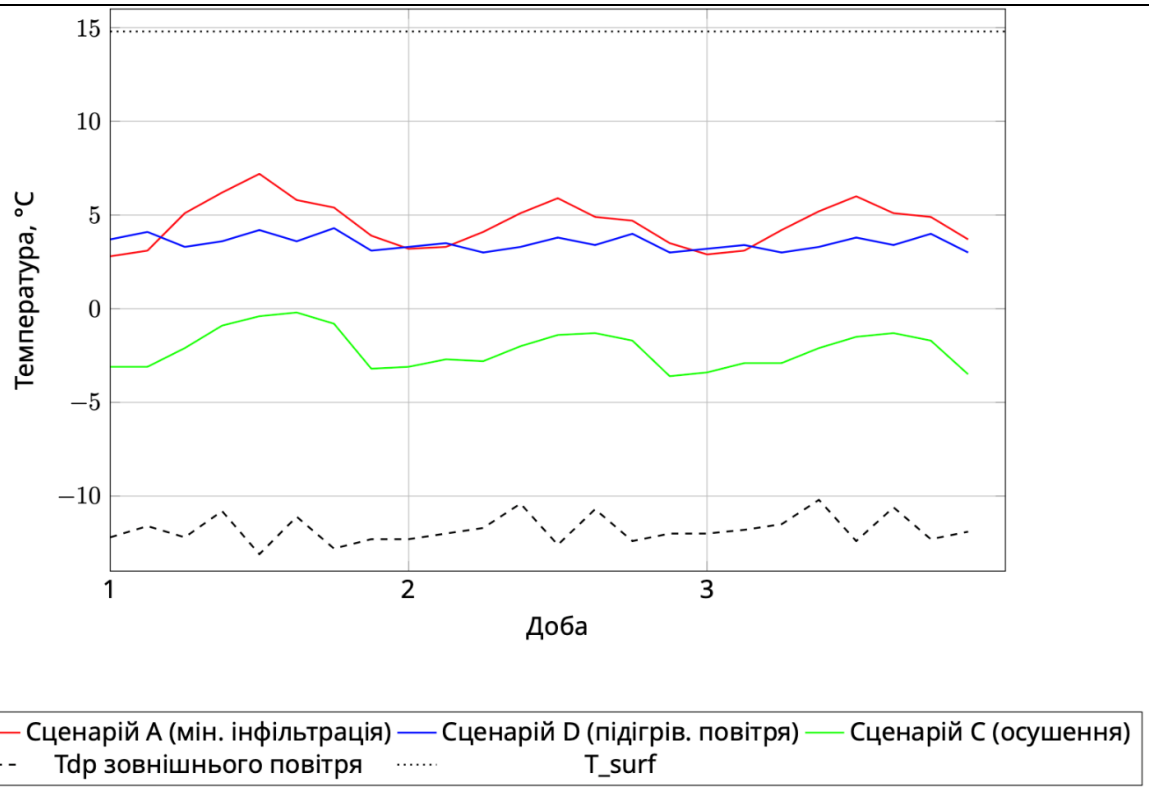

Рис. 2: Динаміка точки роси для трьох сценаріїв у зимовий період.

Зимовий період: динаміка точки роси. Червона крива – базовий сценарій A, де мінімальна інфільтрація; синя – сценарій D із цілодобовою подачею підігрітого повітря; зелена – сценарій C з осушенням; чорна пунктирна лінія – температура стін. Видно, що при всіх сценаріях точка роси завжди нижча за температуру стін, тож конденсат не утворюється.

Таблиця 6.

Результати для зимового періоду (9 діб). Конденсація в жодному режимі не спостерігається; ризик плісняви оцінено за часом $RH > 70\%$.

Сценарій	Опис режиму	Конденсація на стінах	Температура стін T_{surf}	Макс. точка роси $T_{dp,in}$ в приміщенні	Годин $RH_{in} > 70\%$
A (базовий)	Мін. вентиляція (0,1 год$^{-1}$), вдень – короткі провітрювання	Немає (поверхні сухі)	≈14,7…15,0 °C	6-11	0 год (RH макс. ~45%)
C (осушення)	Осушувач 55% + мін. вентиляція	Немає (як у A)	≈14,8…15,0 °C	5-9	0 год
D (вентиляція з підігрівом)	Цілодобова подача свіжого повітря (2 год$^{-1}$), підігрів до +21 °C	Немає (конструкції сохнуть)	≈15,0…15,2 °C	-5-0	0 год

Висновки (зима): Для холодного періоду характерний ефект природного осушення: навіть за мінімального повітрообміну підземне приміщення не накопичує вологу, бо холодне зовнішнє повітря містить мало водяної пари і поглинає надлишок із внутрішнього середовища. Таким чином, підтримання спеціальних режимів (осушення або посилена вентиляція) взимку може не знадобитися – достатньо пасивної інфільтрації і помірного опалення, аби RH_{in} лишалася в межах 40–50%. Активна вентиляція D доцільна хіба що для екстреного просушування дуже вологих конструкцій; інакше її варто обмежувати, щоб не пересушувати повітря надміру.

6. Інтерпретація результатів

Результати, представлені в дослідженні, чітко демонструють ключову роль теплової інерції. Температура поверхні стіни залишається майже незмінною, не реагуючи на добові коливання температури повітря в приміщенні. Це є прямим наслідком величезної теплоємності 0,60 м залізобетону та його зв'язку з термічно стабільним масивом ґрунту. У той же час, точка роси повітря в приміщенні є дуже динамічною. Вона різко зростає з початком робочого дня, коли вмикається вентиляція, що подає вологе зовнішнє повітря, і додатково підвищується через вологовиділення від відвідувачів. Саме цей розрив між стабільно холодною поверхнею та динамічно високою точкою роси є першопричиною конденсації.

Крім того, вологісна інерція конструкцій, їхня здатність до гігроскопічної буферизації, відіграє подвійну роль. З одного боку, вона може згладжувати короткочасні піки вологості. З іншого, при тривалому надходженні вологи ззовні, конструкції поступово насичуються, підтримуючи стабільно високий рівень вологості у приміщенні та сповільнюючи процеси висихання.

Аналіз даних в контексті стандарту ASHRAE 160 дозволяє класифікувати поточну ситуацію як неприйнятну. Тривалі періоди, протягом яких відносна вологість на поверхні перевищує 80%, створюють високий ризик росту плісняви.1 Накопичення рідкої вологи (понад 130 г/м² за тиждень) може призвести до деградації оздоблювальних матеріалів, корозії арматури та пошкодження музейних експонатів, меблів та обладнання. Зимовий період висихання є недостатнім для компенсації такого інтенсивного літнього зволоження.

Стратегії пом'якшення наслідків

На основі аналізу можна виділити дві основні стратегії управління вологісним режимом, кожна з яких має свої переваги та недоліки.

● Стратегія 1: Управління вентиляцією. Найпростіший підхід — провітрювання — може бути контпродуктивним. Як показують дослідження, інтенсивна нічна вентиляція влітку, хоча й забезпечує незначне охолодження, може значно підвищити відносну вологість у приміщенні, оскільки прохолодне нічне повітря часто має високу відносну вологість, що при подальшому охолодженні в підземному приміщенні наближає його до точки насичення. Ефективна вентиляція має бути "розумною": її слід вмикати лише тоді, коли точка роси зовнішнього повітря є нижчою за температуру внутрішніх поверхонь конструкцій. Це вимагає автоматизованої системи контролю з датчиками температури та вологості.

● Стратегія 2: Активне осушення повітря. Найбільш надійним рішенням є усунення першопричини — високої вологості припливного повітря. Модернізація системи вентиляції шляхом встановлення секції осушення дозволить знизити точку роси припливного повітря до безпечного рівня. Дослідження показують, що навіть побутовий осушувач може значно покращити ситуацію, знизивши середню відносну вологість та вдвічі скоротивши час, коли вона перевищує критичний рівень 70%. Для професійного застосування в музеях слід розглядати конденсаційні осушувачі, які є енергоефективними при температурах вище +10°C, або адсорбційні, що працюють і в холодних умовах. Головним недоліком цього методу є значне енергоспоживання.

7. Висновки та проєктні рекомендації

Це дослідження кількісно продемонструвало, що поєднання високої теплової та вологісної інерції підземної залізобетонної споруди та стандартних практик вентиляції створює передбачуваний та серйозний ризик літньої поверхневої конденсації. Нездатність масивної конструкції реагувати на добові теплонадходження призводить до того, що температура її поверхні часто є нижчою за точку роси внутрішнього повітря, яка підвищується через вологу з вентиляційного повітря та від людей. Хоча зимова вентиляція забезпечує ефект висихання, вона не може компенсувати ризики, пов'язані з надмірним зволоженням у літній період.

Традиційні підходи до проєктування, які розглядають огороджувальну конструкцію та систему ОВК як окремі, незалежні системи, є недостатніми для цього класу будівель. Необхідна інтегрована філософія проєктування, заснована на результатах динамічного гігротермічного аналізу, що враховує як теплову, так і вологісну інерцію.

Для адекватної оцінки вологого режиму в масивних конструкціях необхідно використовувати методи нестаціонарного (динамічного) аналізу. Традиційні стаціонарні методи, такі як описані в ДСТУ EN ISO 13788:2022, хоча й корисні для простої оцінки ризику дифузійної конденсації взимку, є принципово непридатними для аналізу досліджуваної проблеми. Ці методи розрахунку гідротермічних показників будівельних конструкцій та їх частин не враховують ключові явища: теплове накопичення , сорбційну ємність матеріалів, добові коливання температури та вологості зовнішнього повітря, а також змінні внутрішні навантаження від людей та обладнання.

Сучасні програмні комплекси, такі як WUFI® (Wärme Und Feuchte Instationär) чи Delphin (Bauklimatik Dresden Software) [8] базуються на розв'язанні системи диференціальних рівнянь зв'язаного тепло- та вологопереносу за EN 15026 і дозволяють реалістично моделювати ці процеси.

Для архітекторів та інженерів має стати стандартною практикою виконання нестаціонарного гігротермічного моделювання при проєктуванні або реконструкції підземних чи масивних будівель для постійного перебування людей. Цей аналіз, заснований на експлуатаційних характеристиках, повинен бути обов'язковим елементом проєктної документації, замінюючи спрощені стаціонарні розрахунки.

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FORMATION OF LOCAL PLASTIC DEFORMATION AREAS IN THE DEFORMATION ZONE DURING DEFORMING BROACHING OF WORKPIECES WITH THROUGH DEFORMATIONS

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Abstract

The article examines some aspects of the technological operation of plastic deformation of holes – deforming broaching. It is used for the manufacture of new and restoration of worn hollow cylindrical products. The article presents experimental data and simulation results aimed at refining the geometric characteristics of the deformation zone during the deforming broaching of cylindrical workpieces with through plastic deformation. It is shown that when the critical pressure is reached in the contact zone between the working surface of the tool and the processed hole of the workpiece, areas of local plastic deformation occur at the beginning and end of contact. This leads to a change in the geometric parameters of the deformation zone, which in turn affects the dimensional and quality parameters of the finished product. The appearance of critical contact pressure corresponds to the critical wall thickness, and its value depends on the tension on the element and the inclination angle of the working element's generatrix. The dependence obtained for its determination. At contact pressures below the critical value, the deformation zone diagram corresponds to the known diagram, which consists of a contact area and two non-contact zones connected to it. At contact pressures greater than the critical value, areas of local plastic deformation appear in the deformation zone diagram at the points where the contact area connects with the non-contact zones.

Keywords: deforming broaching, deforming element, deformation zone, plastic deformation, finite element method, diamond-containing spot method.

Introduction

Deforming broaching (DBR) is a process of cold plastic deformation of cylindrical pipe workpieces made of plastic metals, in which the working deforming elements (DE) are moved with tension along the processed hole. DBR has a number of advantages over cutting hole processing: improvement of the physical and mechanical properties of the processed product material; it reduces the time required for subsequent thermal and chemical-thermal operations by refining the metal structure; it preserves the integrity of the material when restoring worn parts by redistributing the product material to worn areas; there is no negative impact of the process on the environment [1-3]. Therefore, this article discusses some features of deformation in the deformation zone during DBR of products with through deformations.

Literature Review

To obtain the required dimensional parameters and quality indicators of the surface layer of the processed product, the workpiece must go through a deformation stage from its initial state, during which changes in the stress-strain state (SSS) of the material occur. These changes take place in the deformation zone.

The most objective study of the deformation zone during DBR was conducted experimentally at the V.M. Bakul Institute for Superhard materials of the National Academy of Sciences of Ukraine and presented in [2] in the form of a diagram (Fig. 1), which shows the kinematic and geometric parameters of the deformation zone.

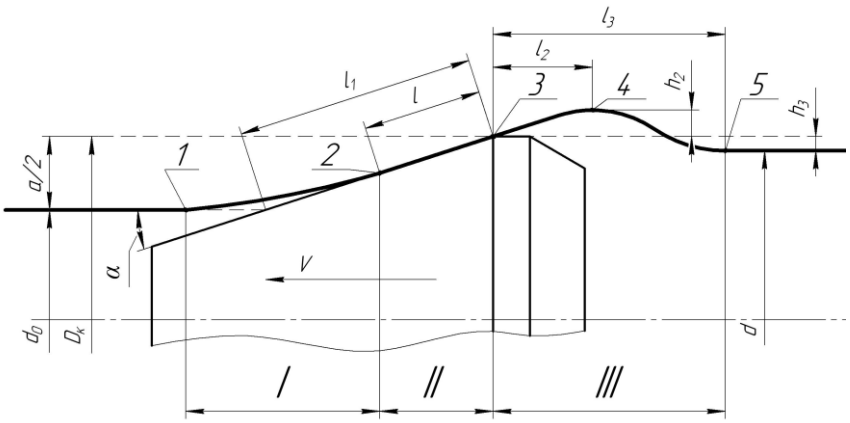

Fig. 1. Deformation zone diagram [2]

The validity of this diagram has been repeatedly proven by other scientists in later works [4-8]. According to it, the deformation zone consists of the contact area between the deforming element and the workpiece – II, and two non-contact zones I and III connected to it (Fig. 1). It should be noted that deformation in different areas of the deformation zone is a single process of product plastic forming and simultaneously determines its stress-strain state and parameters dependent on it in all three areas.

The authors of [2] determined the geometric parameters of the zone using experimental methods and found that the height of the non-contact zone (h_2) changes nonlinearly with changes in the wall thickness of the processed workpiece. When machining workpieces with a wall thickness to hole radius ratio of less than 0.2 ($t_0/r_0 < 0.2$), the height of the non-contact zone increases, but when machining more thick-walled parts ($t_0/r_0 > 0.2$), it begins to decrease. In view of this, in [4] a theoretical model of the deformation zone is presented, constructed using variational principles, and a comparison of the calculated values (Fig. 2) with the experimental data of [2] is carried out.

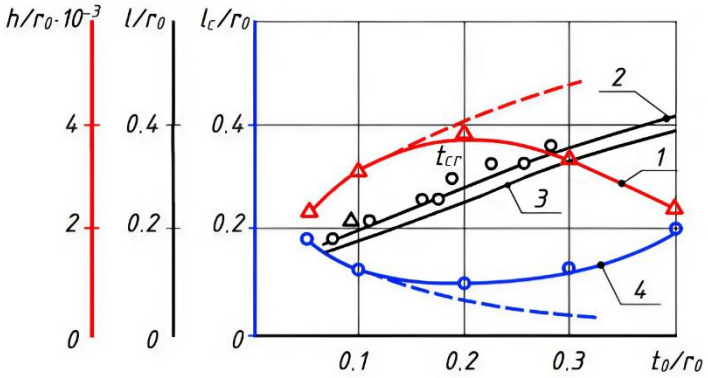

Fig. 2. Dependence of the non-contact zone height (h/r_0) behind the contact area (curve 1); length of non-contact zones: behind the contact area (l_3/r_0) (curve 2), in front of the contact area (l_2/r_0) (curve 3); the length of the contact zone (l_c/r_0) (curve 4) from the thickness of the workpiece t_0/r_0 [4]; experimental data [2]: ○ – steel 20; Δ – steel 10

The theoretical model presented in [4] provides reasonable results for calculating the geometric parameters of the deformation zone, but only when processing shell-type parts ($t_0/r_0 < 0{,}1$). The authors link the increase in contact length when machining thick-walled workpieces (Fig. 2, curve 4) to the occurrence of critical contact pressure in the contact zone, which leads to the formation of a front zone of local plastic deformation in the form of a bulge. The authors do not provide the reason for the extreme nature of the non-contact zone height beyond the contact area (Fig. 2, curve 1).

The complexity of theoretical description, labor intensity, and insufficient accuracy of experimental methods require the use of modern numerical analysis methods, in particular the finite element method (FEM), to study the stress-strain state and shape formation of parts during DBR. Research using FEM was carried out in [7] to study the SSS of each section of the deformation zone when modeling the DBR of a workpiece made of low-plastic material – EN-GJL-200 gray cast iron. The authors simulated the deformation of the workpiece only in the surface layer of the hole, but confirmed the results of earlier studies that the processed material on the inner surface of the hole in the deformation zone at the contact area is under conditions of triaxial volumetric compression.

FEM is also used to study SSS during radial swaging of tubular workpieces [9-11]. The deformation process in such an operation is similar to DBR. In [9], the flow of materials in steel tubular workpieces with different wall thicknesses during rotary swaging of pipes with axial feed without mandrel was investigated. The research was carried out in ABAQUS software based on a 2D axisymmetric finite element model. The authors of the work also found areas of local plastic deformation at the inlet and outlet of the reduction zone. They noted that the deformation of both the outer and inner surfaces of the pipe depends on the wall thickness of the workpiece and the friction coefficient. However, the absence of a specific deformation zone prevented them from establishing the causes of these local areas.

Therefore, to establish the causes of non-monotonic changes in the geometric parameters of the deformation zone, simulation modeling of the DBR process should be performed. Comparison of the simulation results with experimental data will allow verifying the adequacy of the developed models and creating a scientifically sound basis for the development of effective DBR technological processes.

Research Methodology

To conduct experimental studies to determine the length of the contact zone between the deforming element and the workpiece during DBR, a well-known method [2] was used, which consists in applying two diamond-containing spots 4 in diametrically opposite directions to the inner surface 3 of the workpiece 2 (Fig. 3). It is recommended to place spots 4 made of powdered abrasive, which should be harder than the DE material, in the middle of the workpiece length to eliminate the influence of edge effects on the measurement. After performing DBR, characteristic marks in the form of scratches 5 remain on the surface of DE 1, which reflect the contact length.

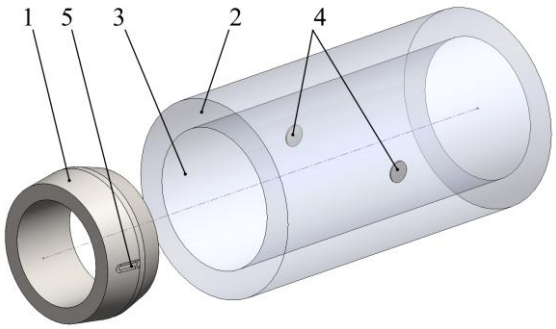

Fig. 3. Diagram of diamond-containing spots application for contact length determination

Pipes made of 12KhN3A steel were used as workpieces. 12KhN3A steel is widely used for the manufacture of parts such as bushings, sleeves, cylinders, piston pins, and the like, which operate under conditions of increased mechanical and tribological loads and require high wear resistance of surface layers. The choice of 12KhN3A as the base material for studying the DBR process has scientific and practical significance. At the same time, the approaches developed and the results of DBR research can be extended to other products made of structural and alloy steels, as well as non-ferrous alloys with a sufficient level of material plasticity.

Before conducting the research, the workpieces were prepared on a lathe. The length of all workpieces was set to 150 mm, the diameter of the hole was 40 mm, and the diameters of the outer surface were: first group – 44 mm, second – 52 mm, third – 60 mm. This allowed us to conduct research on workpieces with different wall thicknesses: $t_0/d_0 = 0.05; 0.15$ and 0.25.

Diamond grains (grain size M7 – M10) were fixed to the treated surface using BF-2 glue. Contact marks on the deforming elements were measured using a BMI-1 instrument microscope with a table linear displacement scale of 5 μm.

A research stand developed by the V.M. Bakul Institute for Superhard materials of the National Academy of Sciences of Ukraine was used to conduct the experiments. The maximum pushing force of the tool was 10 tons.

The deforming elements (Fig. 4) are made of hard alloy type VK-15. The inclination angle of the working cone generatrix is $\alpha = 2°; 4°$ and $8°$, and the width of the cylindrical section is $b_d = 1$ mm. The set of deforming elements consists of 18 items with diameters of $d_d = 40.5; 40.6; \ldots 41.9$ and 42 mm.

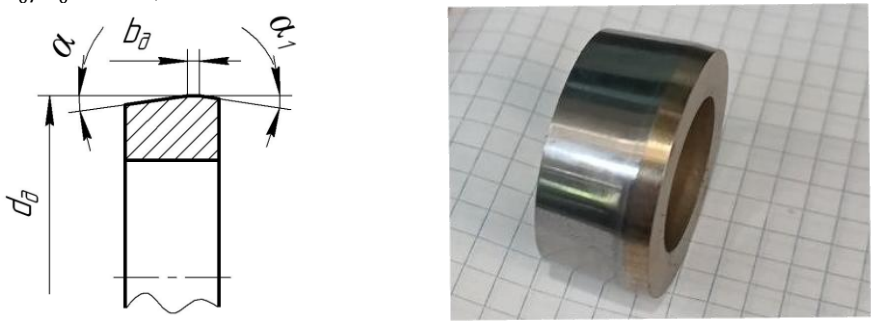

Fig. 4. Deforming element

The general methodology for simulating the DBR process in DEFORM 2D/3D™ V 11.0 software is described in articles [6, 12]. The length of the contact zone was determined as follows: in the Deform postprocessor, the simulation step was displayed at which the DE is located in the central part of the workpiece along the axis during processing, and based on the simulation results, the normal pressure diagram on the inner surface of the workpiece was observed (Fig. 5).

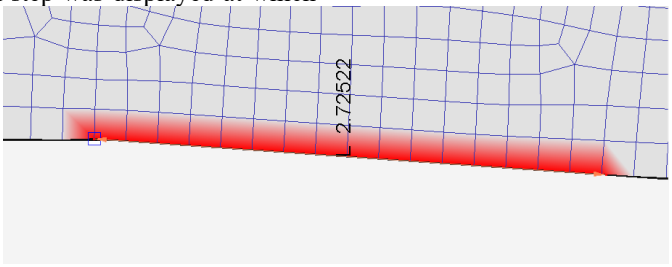

Fig. 5. Determination of the contact length of the workpiece surface with the conical surface DE during DBR simulation

Using the "measurement" tool, the length of the contact zone of the workpiece inner surface with a conical surface DE was recorded according to the normal pressure diagram (Fig. 5).

The height of the non-contact zone during DBR was determined based on the results of simulating the displacement of a pre-created point on the inner surface of the workpiece. The result of the points displacement from their initial position (before processing) in the radial direction is shown in Fig. 6.

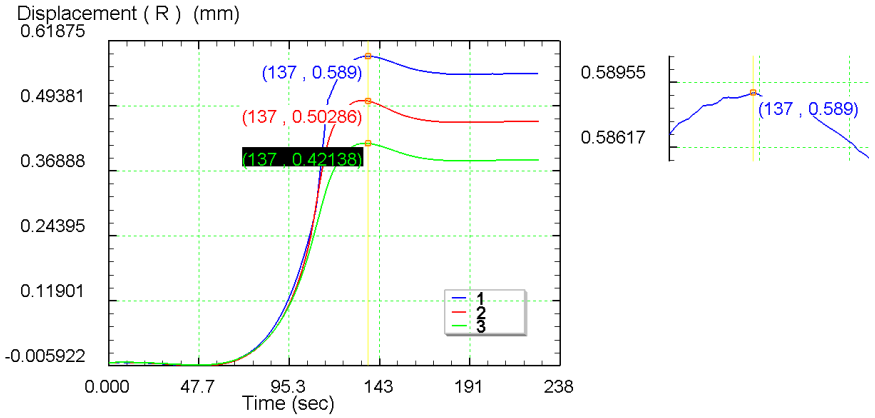

Fig. 6. Displacement of tracked points in the radial direction

Based on the obtained results, the height of the non-contact zone can be determined as the difference between the maximum displacement of point 1 obtained by computer simulation, which is tied to the hole surface, and the known diameter of the cylindrical land of the DE.

The length l_2 was determined by the difference between the Y coordinate of point P1 when it was at the top of the non-contact zone and the contact end point of the workpiece surface with DE.

Results and Discussion

Fig. 7 shows the summary results of experimental studies and simulation modeling of the DBR process with determination of the contact zone length between the deforming element and the workpiece when changing the wall thickness of the workpiece, the tension on the deforming element (Fig. 7, a) and the angle of the working cone of the deforming element (Fig. 7, b).

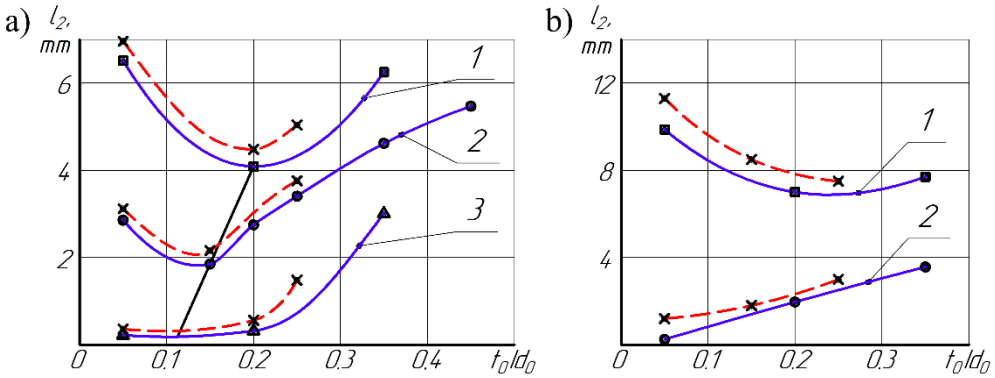

Fig. 7. Dependence of contact length on wall thickness in the simulation of deformation by an element: a) with angle $\alpha = 4°$ and tension on the element a/d_0: 1 – 0.0375; 2 – 0.025; 3 – 0.0125; b) with tension $a/d_0 = 0.025$ and angle α: 1 – 2°; 2 – 8°
- - - - - experimental results, ——— simulation results

Fig. 7 confirms that as the thickness of the workpiece increases, the contact length initially decreases and then begins to increase, with a clear inflection point in the function $l_2 = f(t_0/d_0)$ in the region of critical wall thickness. Using statistical processing of the presented results, we can determine the value of the critical wall thickness at which critical contact pressure occurs in the contact zone:

$$(t_0/d_0)_{cr} = 0{,}07 + 3{,}46\, a/d_0, \quad (1)$$

The results of simulation modeling regarding the height of the non-contact zone (Fig. 8) confirm its extreme nature depending on the wall thickness of the processed workpiece.

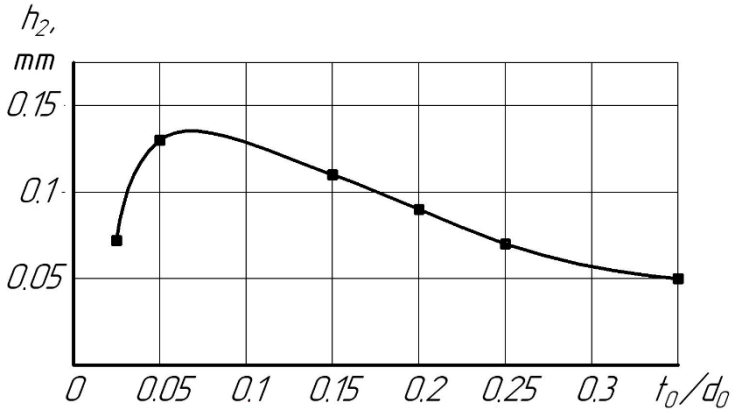

Fig. 8. Change in the height of the non-contact zone obtained by simulation of the DBR process

To identify the reasons for the extreme nature of the contact zone length and the height of the non-contact zone behind the contact area when changing the thickness of the workpiece, let us consider the stress-strain state of the material in the deformation zone obtained by simulation modeling of the DBR process (Fig. 9).

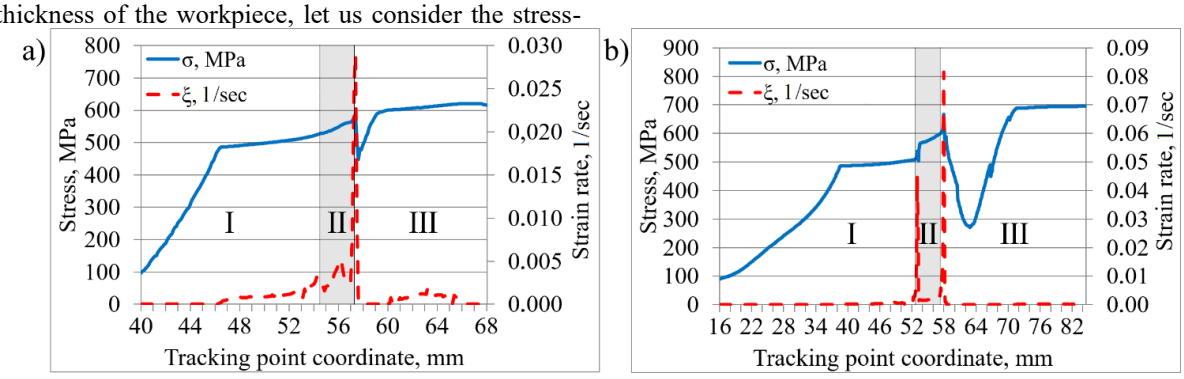

Fig. 9. Change in stress intensity and strain rate ξ on the hole surface during deformation of 12KhN3A steel workpieces with tension on the element $a/d_0 = 0.025$, angle $\alpha = 4°$: a) $t_0/d_0 = 0.05$; b) $t_0/d_0 = 0.35$

The figure shows that the stress intensity on the hole surface gradually increases as the deforming element passes through, but at the beginning of the non-contact zone "III," there is a local drop in stress intensity to $\sigma = 450$ MPa in a thin-walled part (Fig. 9, a) and to $\sigma = 270$ MPa in a thick-walled part (Fig. 9, b). In addition, a slight drop in stress intensity in the second case is also observed at the beginning of the contact zone.

Changes in these areas of stress-strain state are also confirmed by changes in the strain rate. The insignificant value of the strain rate of the thin-walled part metal increases to $\xi = 0.03\ 1/sec$, while in the thick-walled part it reaches $\xi = 0.08\ 1/sec$ at the beginning of the contact zone and $\xi = 0.16\ 1/sec$. at the end of the contact zone. Therefore, it should be noted that with an increase in wall thickness, the change in strain rate increases.

The above indicates that when the contact pressure reaches a critical value, which increases with increasing wall thickness at the beginning and end of contact between the deforming element and the processed surface of the workpiece, areas of local plastic deformation occur. The front zone is caused by the material flowing out of the contact area into the front non-contact zone, reducing its length and increasing the contact zone. The rear zone is caused by the material flowing out of the contact area into the non-contact zone behind the deforming element, which leads to a reduction in the height of the non-contact zone.

To confirm this fact, let us consider Fig. 10, which shows the points of contact between the processed material and the cylindrical section of the deforming element depending on the wall thickness.

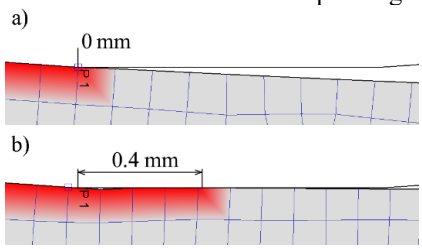

Fig. 10. Areas of the non-contact zone behind the contact zone that are in contact with the cylindrical area of the deforming element during the deformation simulation of workpieces with tension on the element $a/d_0 = 0.025$, angle $\alpha = 4°$, and wall thickness t_0/d_0: a) 0.05; b) 0.35

The figure shows that on thin-walled workpieces (Fig. 10, a) there is no contact between the cylindrical land and the machined surface. As the wall thickness increases, the contact pressure increases, causing axial flow of the machined material from the contact area to the non-contact zone. This is evidenced by the appearance of contact between the workpiece material and the cylindrical land (Fig. 10, b). A similar fact of material flow from the contact zone was obtained by the authors [7], who simulated the contact interaction of a cast iron workpiece during its distribution with a conical punch with radial displacement.

As mentioned in the introduction, it is the deformation zone that affects the dimensional parameters and quality indicators of the surface layer of the processed product. Therefore, changing the height of the non-contact zone will affect the final dimensions of the finished product.

Conclusions

1. It has been established that during deforming broaching in conditions where critical contact pressure is present in the deformation zone, areas of local plastic deformation occur at the junctions between the contact area and the non-contact zones.

2. It has been confirmed that the contact length of the deforming element with the machined surface changes non-monotonically with increasing wall thickness – first decreasing and then increasing due to the appearance of a local plastic deformation zone, which reduces the front non-contact zone and increases the contact area.

3. If there is critical contact pressure in the contact zone, material flows from the contact area onto the cylindrical land of the deforming element, which leads to a reduction in the height of the non-contact zone behind the deforming element.

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